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SUNSHINE RECORDERS AND THEIR INDICATIONS.

REPORT ON THE RESULTS OF A COMPARISON BETWEEN THE SUNSHINE RECORDS OBTAINED SIMULTANEOUSLY FROM A CAMPBELL-STOKES BURNING RECORDER AND FROM A JORDAN PHOTOGRAPHIC RECORDER.

BY RICHARD H. CURTIS, F.R.Met.Soc.

[Read November 17, 1897.]

Historical.

THE registration of bright sunshine was first introduced as an element of meteorological observation by the late Mr. J. F. Campbell, of Islay, at one time Assistant-Secretary of the Board of Health. The first recorder was constructed by him in the year 1853, and was set up at the office of the Board of Health in Whitehall, where the first definite attempt to secure a continuous record of insolation was begun at the winter solstice of 1853, and was continued without intermission for more than twenty years.

In 1857 Mr. Campbell wrote a description of his recorder for the British Meteorological Society, which was printed in the Report of the Council for that year, and from this description the apparatus appears to have been a very simple and inexpensive affair.[1] The lens was formed of "a spherical glass bottle with a short neck," filled with acidulated water; this bottle was placed upon a tumbler, "narrow above, so as not to cut off the rays of light, and wider below, so as to be steady, and filled with the same liquid as the bottle," and was set in a hemispherical bowl of wood, or of white stone. If stone was used the inside was covered "with a coat of some substance which would not wash off, but which would melt at a strong heat"; or if a daily record was desired, strips of ribbon were

[1] *Report of the Council of the British Meteorological Society* for 1857, p. 18.

fastened in the bowl in the path of the focussed rays. But "from the difficulty of getting to the top of the house where the instrument was placed the daily reading was abandoned," and finally only a bowl of hard wood was used, in which the lens was allowed to remain, without being removed, for six months, from one solstice to the next, when the bowl was changed for another which served for a similar period. The record was obtained upon the northern side of the interior of the bowl, which became more or less deeply charred by the sun's rays, according to the amount of sunshine experienced during the period.

Necessarily the record thus obtained left much to be desired. The lens used was 6 inches in diameter, with a focal length of 3 inches, so that the diameter of the bowl was only 12 inches. The traces for

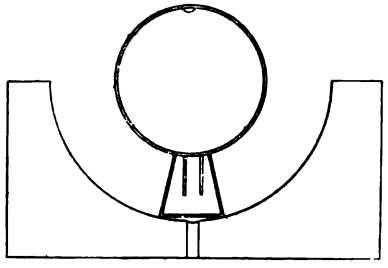


FIG. 1.—Section of Mr. Campbell's original Sunshine Recorder.

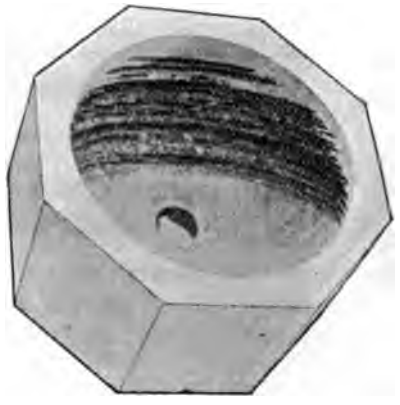


FIG. 2.—Wooden Sunshine Bowl.

successive days, therefore, lay very close together, even at those periods of the year when the declination of the sun changed most rapidly; and it was not only impossible to say how much of the charring of the bowl was due to the sun's action on particular days, or even during periods of several days, but also to distinguish from the total result for any particular period, how much of it was due to *intensity* of insolation, and how much to *frequency*; and equally impossible, as regards the entire six months' record, to obtain anything like an exact quantitative measurement of the total action of the sun upon the wood during that time.

The first improvement which was made in the instrument was the substitution of a lens of solid glass for the fluid lens, of water, or Canada balsam, at first used. In Mr. Campbell's description already referred to he says: "If spherical glass lenses could be made they would be better than liquid lenses, but so far as I can learn, spherical glass lenses have never been made, and they would probably be costly"; and then in a footnote he added: "Since this paper was written a spherical glass lens has been cast by a manufacturer at Manchester; the diameter is 3 inches, and the cost three shillings. It appears to answer the purpose for which it was made." Another glass lens appears to have been made soon after, and was substituted for the original lens at the Board of Health at the close of 1857, where it continued to be used until the year 1875, when it was transferred to the Kew Observatory. This lens,

which is still in existence, does not appear to have been "worked," and it is not truly spherical in shape; in addition to which it has an air-bubble near its centre, which causes a good deal of diffraction of the sun's rays when the ball is placed in certain positions.

Some time prior to 1876, probably during the latter half of 1875, "Mr. Chance of Birmingham got a ball of good glass cast and polished" for Mr. Campbell, and "Sir William Armstrong got a metal bowl turned at his Newcastle workshops to fit the glass."[1] This lens, together with the bowl, which had engraved upon it the motto *Horas non numero nisi serenas*, was handed over to the Astronomer-Royal in 1876, and, under the supervision of Mr. W. Ellis, daily observations were begun with it at the Greenwich Observatory in May of that year.[2]

Before that date, however, in 1875, the lens which had been in use at the Board of Health in Whitehall, had been transferred to the Kew Observatory, where these records in wooden bowls were maintained up to the end of 1896. About this date experiments to obtain daily records were made by Mr. R. H. Scott and Mr. R. J. Lecky, as described in Mr. Scott's paper (*Q. J. Met. Soc.* vol. iii.). The paper is illustrated by a plate of the daily sunshine for September 1875. The earliest cards now at the Meteorological Office are for 1876.[3]

I have already quoted Mr. Campbell's words as to one difficulty which interfered with his getting a daily record, namely the inaccessibility of the recorder in the position it occupied at Whitehall. But that was not the only, or indeed the chief, difficulty to be surmounted. Another, which it was less easy to overcome satisfactorily, was that of fixing firmly and accurately in its place in the bowl, each day, the narrow strip of material, ribbon or card, on which to receive the record. Occasional daily records had been obtained, and Mr. Campbell submitted one to the Society for inspection in 1857. Referring to it he said "the strip was the first plan tried, and but for the trouble it is the best for taking daily observations."[4] In order, however, that the strip of material used might conform to the shape of the bowl, it was necessary that it should be very narrow, and that its shape should be frequently changed; and even then it was by no means easy to place it accurately in the sun's path, changing as that does from day to day, or, when placed, to fix it so that it should not move.

Of course to experienced observers these difficulties were not very serious, but they were sufficiently great to entirely prohibit the use of the instrument by the great majority of meteorologists; and before it could be hoped that observations of bright sunshine would become an element of ordinary observation at meteorological stations, it was necessary that some device should be contrived by means of which the material to receive the burn could be placed in its proper position with ease and certainty. Mr. R. H. Scott, F.R.S., had early suggested the use of a movable holder for the card, which could be shifted as the sun's declination changed, and for some time this was the plan adopted at the Kew Observatory; whilst at the Greenwich Observatory, after trying the plan of cementing

[1] Article by Mr. Campbell on his "Self-Registering Sun-Dial," in *Good Words* for October 1879.

[2] *Quarterly Journal Royal Meteorological Society*, vol. iii. p. 460.

[3] *Ibid.* vol. iii. p. 18.

[4] *Report of the Council of the British Meteorological Society for* 1857, p. 19.

the strip of card to the surface of the bowl, clamps were substituted and found to be more convenient.

Campbell-Stokes Instrument.

The necessary modification of Mr. Campbell's apparatus, which finally overcame the difficulty, was not effected until 1879, when Professor Sir George G. Stokes, F.R.S., met it by discarding the original bowl, and by substituting for it an ingenious form of support, into which a strip of card could easily be slipped, and the use of which was so simple that, when once the instrument was placed in position, its subsequent management could safely be entrusted to the most inexperienced observer.

In this supporter an arc of about 48° of the bowl is divided into three equal parts, and through the centre of each a tangent is drawn, which indicates the surfaces upon which the cards are to lie. These surfaces are

FIG. 3.—Campbell-Stokes Sunshine Recorder.

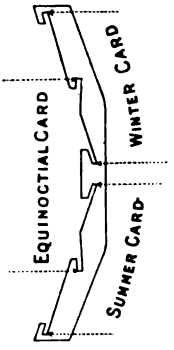


FIG. 4.—Section of Bowl.

then revolved so that the middle one becomes a zone of a cylindrical surface, with a zone of a conical surface both above and below it; and "these being developable surfaces, bits of card may be applied so as to fit them accurately."[1] These surfaces are so placed that they differ but very little indeed from the spherical surface of the bowl they are intended to supersede, and in supports of the size indicated by Sir G. G. Stokes the maximum error due to this cause need not exceed 0·01 inch. An ingenious arrangement of grooves, obtained by undercutting the metal of which the support is made, in the manner shown on the accompanying diagram (Fig. 4), allows at once of the use of a card sufficiently wide to avoid any risk of losing the trace when it passes from one zone to another, and also affords a very convenient method of placing the cards securely in their proper positions.

This modified form of Campbell's recorder is now generally known as the "Campbell-Stokes," by which title justice is done to the two men whose joint creation it is. It was first brought out towards the close of the year 1879, and since then it has come into very general use.

[1] *Quarterly Journal Royal Meteorological Society*, vol. vi. p. 84.

Photographic Recorders.

This is not, however, the only form of recorder in use in this country. For some years before the evolution of Mr. Campbell's "Self-registering Sun-Dial," attempts had been made to utilise for the same end the action which light was known to have upon certain chemical substances. As far back as 1838 the late Mr. T. B. Jordan proposed a plan for a self-recording "Heliograph," which was "to yield an accurate account of the intensity of the light for every minute of the day, and permanently to register its indications," and in which "the peculiarity of the tint" of a strip of sensitised paper, moved by a clock, was to "show whether the sun were shining or obscured, and the degree of obscuration."[1]

This plan appears never to have come into use; but several years later. when the Campbell-Stokes recorder had caused more general attention to be drawn to the subject, and when also considerable advances had been made in our knowledge of photography, Mr. Jordan's son, Mr. J. B. Jordan, following somewhat his father's lead, brought out an extremely simple apparatus, in which the sun's apparent motion through the heavens was utilised in order to dispense with the use of a clock, and of the complex details a clock involved.

Jordan Recorder.

Mr. Jordan introduced his recorder in the year 1885. It consists of a cylindrical box, around the inside of which a slip of sensitised paper can be wound. The box is light-tight except for a small hole on either side, and forms in fact a "pin-hole camera." The box being set up with its axis in the plane of the meridian, the sunlight enters it during the morning hours through the hole on its eastern side, and after noon through the hole on the western side. The dot of light thus thrown upon the paper leaves its mark behind it as it travels around the inner surface of the box with the motion of the sun through the heavens. The trace is obtained upon a strip of paper coated with a mixture of a ferric salt and potassium ferricyanide, which under the action of light changes into Prussian blue (ferrocyanide of iron); all that is required to "fix" the record, and render it permanent, being to wash it in water as soon as it is removed from the box. In a later and improved form of the instrument, two semi-cylindrical boxes, placed side by side, are used instead of the single cylinder at first employed.

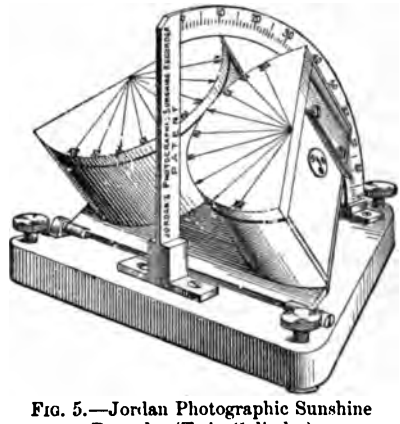


FIG. 5.—Jordan Photographic Sunshine Recorder (Twin-Cylinder).

Other forms of recorder, both photographic and burning, have been

[1] "A new mode of Registering the Indications of Meteorological Instruments," by T. B. Jordan, in the *Report of the Royal Cornwall Polytechnic Society* for 1838.

suggested, but as for the most part they are merely modifications of one or the other of the two forms just described, they need not here be further referred to; speaking broadly, the Campbell-Stokes and the Jordan instruments are the only forms which have come into general use.

Comparability of the Records.

As regards simplicity, there is very little indeed to choose between these two instruments; neither of them, when once properly set, requires any further attention than to have a fresh strip of card or paper substituted at sunset for that which has been in the instrument during the day, with the additional slight trouble in the case of the photographic of washing the paper for a few minutes in order to "fix" the record.

But as regards the records themselves it will at once be recognised that there is a very important difference between the two. In the case of both instruments, the registration is effected by the action of the solar rays; but whilst in the "Campbell-Stokes" it is their *burning* power which is registered, in the "Jordan" it is their *actinic* effect which produces the trace—in other words, the one is a record of sun-*heat*, whilst the other is a record of sun-*light;* and whilst it is probably true that, as a rule, both the burning and chemical effects vary directly with the brightness of the sun's rays, yet it by no means follows that the conditions which will produce the most active chemical action must necessarily, and always, be those most favourable for burning.

The question therefore arises as to how far the results yielded by these two types of recorders may with safety be compared with each other? and a satisfactory answer to the question is important, because of the necessity for making such a comparison, directly it is required to deal with sunshine statistics obtained over even a relatively small area, since it almost invariably happens that, whilst at many of the stations burning recorders are in use, at others the records are photographic.

Attempts have already been made by some observers to deal with this question, but so far as I know no results, of anything like an authoritative character, have ever been obtained, or at any rate published; and in the case of one attempt, the results of which have been perhaps more often quoted than those of any other, the conditions were such as to make the comparison not merely worthless but positively misleading.[1] A pretty general opinion seems to exist that photographic instruments yield a larger record than do instruments of the burning type similarly exposed, but I have not been able to find that this opinion rests upon any satisfactory basis of ascertained fact.

In order, therefore, to set the matter at rest, the Council of this Society, in the spring of 1896, determined to institute a comparison between the "Campbell-Stokes" and "Jordan" recorders, which should thoroughly test the capabilities and idiosyncrasies of the two instruments, and at the same time afford reliable data for determining how far the

[1] The observer who is responsible for the results here referred to does not appear to understand the management of the Campbell-Stokes instrument. In a recent letter he says: "I cannot by any means in my power properly adjust the focus so that the cards shall always be at a true distance from the ball; at the present moment . . . it is at some parts of the day at least, one-eighth of an inch out of focus; in some cases it gets as much as a quarter of an inch out of focus!"

records yielded by the one may be accepted for comparison with those obtained from the other.

Conditions to be Complied with.

To render such a comparison satisfactory, there are two or three points to which attention must be paid, viz. :—

(1) Care must be taken that the instruments employed are in proper adjustment, and that they are fair examples of the types they represent.

(2) They should occupy positions entirely similar in every respect as regards their exposure to the solar rays; and further, the positions chosen should be such as to give them an absolutely clear horizon, so that their capabilities for registering early and late sunshine may be properly tested.

(3) The comparison should extend over a period of time sufficiently long to test the instruments under the varying conditions of different seasons; and also long enough to afford the means of detecting any purely fortuitous circumstances which might arise, and unfairly prejudice either of the instruments employed.

It is believed that in the present instance each of these conditions has been met.

The "Campbell-Stokes" instrument used was one belonging to Mr. Dowson, which has been in continuous use in its present position ever since 1880. It has been several times inspected by Mr. Marriott on behalf of this Society, as well as by the Inspectors of the Meteorological Office; and in addition, in the autumn of last year, in view of these experiments, I went myself to Geldeston specially to examine it, and there is no doubt as to its fully satisfying the conditions named in paragraph 1. The lens weighs 3 lbs. 1 oz., and is white in colour and perfectly clear. The "Jordan" instrument employed was a "twin-chamber" instrument obtained for the purpose from Messrs. Negretti and Zambra, by whom also the whole of the sensitised sheets used during the experiment were supplied.

The Council were fortunate in being able to secure the co-operation of Mr. E. T. Dowson, F.R.Met.Soc., of Geldeston, Norfolk, who at their request undertook the task of obtaining the observations, and maintained the instruments in action, without a break throughout the whole time the experiment lasted. Mr. Dowson was already well known as an experienced and thoroughly reliable observer, and the confidence the Council felt in placing the observational part of the experiment in his hands has been amply justified by the results.

Position of the Instruments at Geldeston.

The instruments were placed 22 feet above the ground on the roof of an outhouse adjoining Mr. Dowson's residence; the "Jordan" being put right in front of the "Campbell-Stokes," and touching it, but in such a way that it could not possibly obstruct the latter in any degree. The horizon was a perfect one, and the only obstruction experienced at all was from a chimney which cut off the sun for a few minutes after 10 a.m. near the winter solstice, but this in no way affected the results of the comparison.

The house stands upon a gentle slope, which forms the northern side of a broad shallow valley through which the river Waveney flows from west to east, the trees which crown the opposite side of the valley, about a mile and a quarter distant, being just about level with the position of the recorders. The surrounding district, though slightly undulating, may for all practical purposes be considered as level, with the sea about 10 miles east from the instruments; and as the country is purely agricultural there is no risk of the sunshine being interfered with by smoke, or other artificial obstructions, such as might occur in the neighbourhood of large towns.

FIG. 6.—Showing Position of Sunshine Recorders at Geldeston.

The observations were definitely commenced on June 1, 1896, and were continued without break until June 4, 1897—a period which was considered sufficiently long for the purpose. Traces were also obtained on a few subsequent days when it was thought the conditions were specially favourable for securing a record near the times of sunrise and sunset.

The records were handed over to me each month to be dealt with, and the method I adopted in doing so was as follows :—

The curves from both instruments were measured independently by myself and by two gentlemen, both of whom possessed a good deal of experience in dealing with sunshine traces, and who willingly gave me their assistance. As a rule each month was dealt with separately, and soon after the records were received ; but in order to guard against bias in any direction neither tabulator saw the measurements of the others, nor did he know when tabulating the cards of the one instrument what had been recorded for the same days by the other instrument. The measurements were therefore absolutely independent, and I am convinced that a

perfectly unbiassed attempt was made by each tabulator to obtain a true interpretation of the records before him.

Tabulation of the Records.

It may be an advantage here to describe more particularly the characters of the traces afforded by the two types of instrument.

The trace yielded by the "Campbell-Stokes" should, if the lens is of the proper focal length to fit the bowl in which it is placed, and is properly adjusted within it, be a narrow, sharply defined, burn; going right through the card in bright sunshine, but only charring its surface when the sun's rays are weaker, and passing into a mere discolouration, which presently fades away altogether, with the waning rays of the setting sun. If the sunshine has been continuous the measurement of such a trace is of course perfectly simple, the only point on which two persons could possibly differ being as to the exact moment at which the trace begins at sunrise, and ends at sunset. When, however, the sunshine has been intermittent, the measurement of the trace affords more room for diversity of opinion. If the sun shines brightly for only two or three seconds it will make a burn which may measure as many minutes upon the time-scale of the card, and will be almost or quite as large as if the sun had shone continuously during the whole time indicated by the trace. This exaggerated record is due in part to the breadth of the sun's image, but also to a lateral smouldering of the card, and although the smouldering does not exceed certain very narrow limits, and ceases directly the sun's rays are withdrawn, it becomes impossible to say in such cases how much of the burn is due to this cause.

No strict rule for the guidance of observers can be laid down, but the practice recommended by the Meteorological Office is to measure the whole of the well-charred trace, but not to measure the penumbra; whilst in the case of fainter sunshine, when the card is merely discoloured, —as at sunrise and sunset,—to measure all that can unmistakably and easily be seen.

Under these rules there need be no fear that *less* than the true amount will be recorded; the error, if any, is more likely to be in the opposite direction, and the more discontinuous the trace the greater is the error likely to be. We have then in this trace something which may be recognised as a definite minimum of solar action. No trace is made unless the sun's rays, when brought to a focus by a spherical lens of a given diameter, possess sufficient heat to at least discolour a strip of blue-tinted card; and certainly if the lenses used are of the same kind and size, the traces obtained by different instruments should be strictly comparable *inter se*. This is a point which appears to me to be of great importance.

The trace obtained from the "Jordan" instrument is a narrow band, about an eighth of an inch wide, running across the strip of paper; in bright sunshine it is dark blue in colour, but with fainter sunshine the blue is less intense, and with the feeble rays of sunrise and sunset it fades away into the pale bluish-grey tint common to the whole surface of the paper.

The measurement of this trace when the sunshine has been continuous

is as simple as in the case of the charred trace, except that it may possibly be a little less easy to decide its exact terminal points. But with intermittent sunshine the difficulties of measurement are decidedly greater. The image of the slit thrown upon the paper is fully two minutes wide, by the time-scale of the trace; and therefore the tendency here, as with the Campbell-Stokes instrument, is for the trace to err, if it do so at all, in excess of the truth. But it does not always happen with intermittent sunshine that the trace ends and begins again abruptly. Very often the trace at such times is almost continuous, and is merely broken up into a number of bands of varying depth of colour, some quite dark, and others so faint that it is difficult to say whether or not they are any stronger than the general tint of the paper, and not seldom the difficulty is increased by a general discolouration of the paper resulting from diffused light or some other cause. It is quite clear that in this case it is not so easy, as in the case of the burning recorder, to recognise the indication of a definite minimum of solar power, because the minimum amount of light necessary to produce a trace will depend entirely upon the sensitiveness of the paper employed, which, as I shall presently show, may vary considerably.

In the case of neither instrument is any regard paid when measuring the trace to the *intensity* of the solar action, and the total amount is always entered as "bright" sunshine, however weak some of it may have been; so that the question to be settled here is, what is the lightest tint of colour which ought to be accepted as due to direct sunshine, sufficiently strong to justify the term "bright"?

Many observers tabulate everything which can by any possibility be construed into a trace, and even use a lens to assist them in detecting one; but I am doubtful whether "*bright* sunshine" is quite the proper term to apply to such feeble insolation as could scarcely discolour the paper when the sun was well above the horizon. However, after very carefully studying the traces obtained in the course of this inquiry I am quite unable to lay down any better rule for dealing with them than the broad one already stated as a guide for the Campbell-Stokes trace, namely, that "only such trace should be measured as can unmistakably be seen"; by which I mean such as is decidedly darker than the general tone of the paper, and can be seen without having to search for it with a magnifying glass. How this rule is to be read into the varieties of trace which constantly crop up from day to day every observer must, of course, decide for himself.

There is certainly at all times an amount of diffused light in the box, and indeed an image of surrounding objects, if they are at all brightly illuminated, is thrown upon the paper; but if the sensitiveness of the paper is sufficiently low no appreciable effect is produced upon it by this light, beyond perhaps the general grey toning to which I have referred, and upon this the trace made by the stronger direct rays of the sun ought, if they deserve the term "bright," to stand out with distinctness.

The real difficulty, without doubt, lies, first, in determining the degree of sensitiveness the paper should possess, and then, when a formula has been decided upon, in securing uniformity in its use.

But, with regard to this second point, there are at least three causes which may affect the result:—

(1) Variations in the purity or strength of the chemicals, and in the kind of paper employed;

(2) The length of time which is allowed to elapse after sensitising before the papers are used;

(3) The amount of washing the papers undergo in "fixing";

and to these should probably be added the hygrometrical condition of the atmosphere whilst the paper is in the recorder, and perhaps to a lesser extent the effect of damp at any time after sensitising and before exposure.

As an illustration of the importance of the first of these points I may mention an experience gained in the course of the present experiment. A fresh set of papers supplied by Messrs. Negretti and Zambra were found to be unmistakably less sensitive than their predecessors; and upon referring to the makers we were informed that the same formula had been used as in previous cases, and that the chemicals had been supplied by the same manufacturers, and professed to be of the same strength and purity as before, although there could be no doubt that their strength in this instance was not the same.

Results of the Comparison.

It is time now to deal with the actual results derived from this comparison of the two types of recorder.

Before commencing the tabulation of the curves each tabulator had before him the general rule I have already referred to, and also a caution against excluding, in either set of curves, anything which ought to be measured; beyond this, however, he was left to deal with the curves entirely in accordance with his own judgment. The results are exhibited in the following tables, where the letter at the head of the columns serves to denote the different tabulators. For about half the period measurements were tabulated for each hour, but for the remainder the daily totals only were recorded; but inasmuch as the differences between the two instruments appeared to vary quite irregularly, it has been deemed sufficient to give only the totals for each month in the tables which follow.

Table I. gives the monthly and yearly amounts derived from the Campbell-Stokes cards. Slight differences are shown from month to month between A and B, but these balance each other, and the yearly amount obtained by each is the same. On the other hand, C almost invariably made more of the trace than the others, the extreme difference being between A and C in July, when it amounts to 6 hours. C's yearly total exceeds the others by 22 hours, or nearly one and a half per cent. On the whole, however, and bearing in mind the conditions of the case, I think the results of the three measurements are perhaps as close as could have been anticipated.

I am, however, able to give some additional data as to the amount of agreement which may be looked for in independent measurements of cards obtained from Campbell-Stokes recorders. Recently remeasurements of several years' cards from seven observatories of the Meteorological Office were made at the Office, the original measurements having been made at the observatories. How far the original measurements had been made by different individuals, at each observatory, I cannot say; but the remeasurements for each place were pretty equally

TABLE I.—Monthly Amounts of Bright Sunshine derived from the Records of the Campbell-Stokes Burning Recorder, as measured independently by three Tabulators.

1896-97.	A.	B.	C.
	hrs.	hrs.	hrs.
June	254	252	256
July	241	245	247
August	125	126	128
September	104	102	105
October	81	79	81
November	77	76	78
December	33	32	32
January	43	43	43
February	47	47	48
March	114	117	117
April	138	138	140
May	243	243	247
Total . . .	1500	1500	1522

divided amongst four persons; and the differences for the month of May, for twelve consecutive years, are given in Table II.

TABLE II.—Differences obtained on Remeasurement of Twelve Years' Sunshine Cards (Campbell-Stokes) for the Month of May, from Seven Observatories.

	Meteorological Office Remeasurement.						
Year.	Valencia.	Armagh.	Glasgow.	Aberdeen.	Falmouth.	Stonyhurst.	Kew.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
1881	−3	−5	+ 1	− 5	−4	+2	+4
1882	−3	−5	+ 3	−10	+2	−7	+2
1883	0	+3	+ 6	− 5	−6	−1	−1
1884	−2	+8	+14	− 4	+1	−4	−3
1885	−5	+7	+16	− 9	+6	+1	−5
1886	−1	+4	+ 2	− 5	+5	−4	+1
1887	−4	+2	+ 6	− 5	+4	−2	−3
1888	+5	−1	+ 1	− 9	−4	−2	−5
1889	−1	+1	− 2	− 5	+1	−4	+1
1890	+3	−2	+ 1	−12	−4	+7	−3
1891	+3	−5	+ 3	−11	−6	+3	+3
1892	+3	−2	− 1	−10	−2	+2	+2
Mean	+0·4	+0·4	+4·2	−7·5	−0·6	−0·8	−0·6

It is evident from Table II. that the observers at the two Scotch stations had a decided bias, although in opposite directions, in making their measurements, the one being a good deal below, and the other still more in excess, of the remeasured amounts; but with the exception of these two places the mean difference on the series of years is, in every case, less than one hour, and supports the contention that these traces can be tabulated by different persons with a very close approach to accuracy.

Table III. shows in a similar form to Table I., the results obtained, by the same persons, from the "Jordan" charts, and here a greater diversity of opinion amongst them is manifested. Except in June and

August, A's amount is always in excess of B's amount, and with the exception of July B is always in excess of C, so that it is evident there must have been a systematic difference in the minimum standard adopted by the three. The amount of difference varies considerably from month to month, and the yearly total obtained by B is only 97 per cent, and that of C only 92 per cent, of the amount given by A.

TABLE III. — MONTHLY AMOUNTS OF BRIGHT SUNSHINE DERIVED FROM THE RECORDS OF THE JORDAN PHOTOGRAPHIC RECORDER, AS MEASURED INDEPENDENTLY BY THREE TABULATORS.

1896-97.	A.	B.	Percentage of the Amount by A.	C.	Percentage of the Amount by A.	Percentage of Amount in Col. 1 to that in Col. 1, Table I.
	hrs.	hrs.	%	hrs.	%	%
June . .	232	235	+1	233	0	- 9
July . .	225	209	- 7	211	- 6	- 7
August . .	116	121	+4	108	- 7	- 7
September .	99	92	- 7	88	- 11	- 5
October . .	70	69	- 1	61	- 13	- 14
November .	69	64	- 7	60	- 13	- 10
December .	23	22	- 4	21	- 9	- 30
January . .	32	31	- 3	30	- 6	- 26
February . .	45	41	- 9	37	- 18	- 4
March . .	113	107	- 5	98	- 13	- 1
April . .	122	120	- 2	109	- 11	- 12
May . .	217	211	- 3	199	- 8	- 11
Total . .	1363	1322	- 3	1255	- 8	- 9

If these amounts are compared with those in Table I. it will be seen that each tabulator obtained a smaller amount from the photographic than from the burned traces; and that A's amount for the year was only 91 per cent, B's 88 per cent, and C's only 84 per cent of the amounts obtained by both A and B from the Campbell-Stokes records. These differences were so large that I thought there could be no doubt that after all a too stringent view had been taken of the minimum indication of "bright" sunshine. The whole of the photographic curves were therefore remeasured, and a new tabulator, D, was substituted for A. Of course the first set of values was not referred to, and it was arranged that in this instance the minimum limit was to be placed as low as possible, and that the curves should be measured to their fullest extent.

The results of this second tabulation are shown in Table IV.

I do not think there can be any doubt that in this instance the limit was placed as low as possible. The tabulators were anxious to make the totals as high as they conscientiously could, and I think the amounts given may be accepted as full measures of the traces. The differences between the totals in this table and those in Table III. are very considerable, and if they are accepted as fair examples of the range which may be looked for in the interpretation of the same records by different persons, or by the same person, only using a different standard, it certainly indicates a weak point in the photographic records. But even these increased amounts are upon the whole less than those yielded by the Campbell-Stokes cards. Taking A's measurements of the latter in Table I. as the

standard, and comparing with them D's photographic values in Table IV., the monthly amounts of the latter vary from 6 per cent above, to 30 per cent below, those of A; whilst the yearly total of D is 3 per cent, and those obtained by B and C are both 6 per cent, less than A.

TABLE IV—Monthly Amounts of Bright Sunshine derived from a Remeasurement of the Jordan Photographic Curves.

1896-97.	B.	Percentage of Amount by First Measurement.	C.	Percentage of Amount by First Measurement.	D.	Percentage of Amount by D. from the Campbell-Stokes Amount got by A in Table I.
	hrs.	%	hrs.	%	hrs.	%
June . .	251	+ 7	246	+ 6	257	+ 1
July . .	227	+ 9	237	+ 12	242	0
August . .	131	+ 8	127	+ 18	132	+ 6
September .	109	+ 18	106	+ 20	106	+ 2
October . .	78	+ 13	74	+ 21	79	- 2
November .	71	+ 11	74	+ 23	72	- 6
December .	24	+ 9	27	+ 29	23	- 30
January . .	32	+ 3	34	+ 13	34	- 21
February . .	40	- 2	43	+ 16	45	- 4
March . .	107	0	118	+ 20	114	0
April . .	124	+ 3	123	+ 13	131	- 5
May . .	218	+ 3	207	+ 4	219	- 10
Total . .	1412	+ 7	1416	+ 13	1454	- 3

In these tables only the monthly totals are given, and these do not exhibit the extent of the variations between the records of the two instruments from day to day. These daily variations are apparently very erratic, and do not seem to be related either to temperature, humidity of the air, amount of sunshine, or any other condition of weather, and their amplitude varies very much and quickly. To take one instance, the Jordan record gave on one day nearly three and a half hours *more* than the Campbell-Stokes, the next day it gave an hour less than that instrument, and the day following that two hours less. The sums of these daily differences for each month are as follows:—

TABLE V.—Sums of the Differences between A.'s Measurements of the Campbell-Stokes Cards and D.'s Measurements of the Jordan Cards.

	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
Jordan in *excess* of C.-Stokes.	10·9	12·6	8·8	7·8	2·0	0·7	0·1	0·8	1·8	8·8	10·3	5·4
Jordan in *defect* of C.-Stokes.	8·7	12·5	4·2	5·5	8·6	6·4	10·3	9·9	3·4	9·2	16·5	30·1

Broadly, this table divides itself into three parts, from June to September, October to February, and March to May; the divisions being caused by the remarkable decrease in the *plus* differences shown in the middle period. I thought at first that this might have been due to the use during this interval of less sensitive papers, but the surmise is not

supported by the fact that even when the *plus* differences are larger the *minus* differences are larger also.

Quite recently I found that Dr. R. E. Lord, of Colwyn Bay, had for some time past been making a comparison between the records of a Campbell-Stokes and a Jordan recorder, and he has kindly supplied me with the figures he obtained from the two sets of curves. His Jordan instrument is one of the old pattern, single-chamber recorders, and I am not sure that his instruments quite fulfil the conditions I have named on p. 7, as essential for such a comparison. His measurements of both curves were made without a scale, and I believe Dr. Lord's practice was to take a liberal view of what should be accepted as "bright sunshine," and his measurements certainly do not err in the direction of being too small.

Table VI. gives the monthly totals he obtained for sixteen months.

TABLE VI.—Monthly Amounts of Bright Sunshine registered at Colwyn Bay, North Wales, by a Burning and by a Photographic Recorder, measured by Dr. Lord.

1896.	Amount by:		Diffce. C.S.-J	1897.	Amount by:		Diffce. C.S.-J.
	Campbell-Stokes.	Jordan.			Campbell-Stokes.	Jordan.	
	hrs.	hrs.	hrs.		hrs.	hrs.	hrs.
May . .	314	313	+ 1	January . .	54	53	+ 1
June . .	230	235	− 5	February . .	64	71	− 7
July . .	210	209	+ 1	March . .	123	139	− 16
August . .	160	164	− 4	April . .	158	167	− 9
September .	87	99	− 12	May . .	285	288	− 3
October . .	81	74	+ 7	June . .	196	207	− 11
November .	77	79	− 2	July . .	255	265	− 10
December .	39	41	− 2	August . .	230	236	− 6
			Total for sixteen months .		2563	2640	− 77

In this case also considerable variation is shown in the daily totals yielded by the two instruments, but the monthly amounts are generally, although not always, higher with the photographic instrument, and the total for the sixteen months is 77 hours, or 3 per cent, more by that instrument than by the burning recorder. This result does not altogether agree with that which I have already detailed, but I attach less importance to it than I do to the figures given in Tables III. and IV. because of the reasons I have already named, and also because I am not able to speak so confidently as to the conditions under which the experiment was carried out as I am in the case of the Geldeston records. I ought also to add that the lens of Dr. Lord's burning recorder is the largest I have ever met with, being no less than 4·3 inches in diameter, and weighing more than four and a half pounds. Although it is placed in a bowl of the usual size yet, owing to the high refractive index of the glass of which it is made, its focal length is so short as to bring the sun's image very fairly upon the card. It is, however, a question whether such a lens would burn as readily in weak sunshine as the 4-inch lens of crown glass and longer focus.

Deductions drawn from the Comparison—

A. *Campbell-Stokes Recorder.*

The conclusions which I think may fairly be drawn from all these figures are as follows:—

(1) In the case of the Campbell-Stokes instrument the records are capable of being measured by different persons with very similar results, and with a very fair degree of accuracy.

(2) The records of the Jordan instrument afford room for much greater difference of opinion as to what ought to be tabulated, and consequently measurements of the Jordan curves are open to considerably more uncertainty than are measurements of the Campbell-Stokes curves.

(3) The photographic record is not, upon the whole, in excess of that of the burning instrument; occasional large differences between the two records seem unavoidable, but these are not always in the same direction, and when for such a period as a month the whole of the photographic trace which can be distinctly seen, but including portions of it which are decidedly faint, has been measured, the amount will generally approximate sufficiently to that of the Campbell-Stokes instrument to allow of records obtained from both forms of instrument being compared *inter se*.

These are deductions based upon the figures contained in the tables; but there are other very important points suggested by the investigation, although not arising immediately from the figures, to which attention ought also to be drawn.

Dealing first with the Campbell-Stokes instrument, it appears to me that it possesses a great advantage over photographic instruments in that, given certain conditions as to lens, and mounting, the records obtained with it from different observatories are absolutely comparable with each other; and also that it is possible to fix a distinct standard, which can easily be recognised, as the inferior limit of what should be regarded as "bright sunshine." If it is agreed to define that limit as the degree of solar radiation which, when concentrated upon a bluish tinted card by a spherical crown glass lens 4 inches in diameter, is competent to produce a brown mark upon the card, I do not think it possible that any sunshine, the warmth of which is able to produce an appreciable effect upon either animal or vegetable life, is likely to escape registration. The instrument was not intended to be an actinometer, and the registration of the duration of *light*, merely, however bright, is not its function; it is only intended to act when the sun's rays have attained a certain degree of heat-power indicated by the effect named; and only then is this arbitrary use of the term "bright" justified.

To secure this uniformity of result regard must be paid to two or three points in the instrument itself, and first of all to the lens. It is essential that all lenses should be made of the same kind of glass; that they should be similar in size; and that they should properly fit the bowls in which they are placed. The kind of glass which has most generally been used, and which appears to be best suited for the purpose, is crown glass; and the diameter recommended by Sir G. G. Stokes is 4 inches. As a matter of fact, however, I can say from experience that these conditions are often varied. Quite recently Mr. J. Baxendell, F.R.Met.Soc., of Southport, wishing for a duplicate instrument, received

one in which the lens, although of the same diameter, weighed one-third more than the lens of the instrument he already possessed, and registered something like 20 per cent less sunshine! I have already mentioned that the lens of the Colwyn Bay instrument measures 4·3 inches in diameter, and weighs 4 lbs. 10 oz., whilst the bowl in which it is placed is of the same size as is used for the ordinary 4-inch lenses; that this lens should fit the bowl as well as it does, appears to me to be purely accidental. The only other case I will mention is that of an instrument which was recently in my hands, in which, as received from the maker, the lens would not, in brilliant sunshine, make any mark whatever on some parts of the card, and would only discolour it in any part.

Equally as important as the lens is the bowl, which must be of such a size that the card shall be exactly in the focus of the lens throughout the entire day. I have already pointed out that the construction of the bowl makes it impossible that its surface shall be strictly in focus at all points, but the error need only be a very slight one, and is negligeable if the bowl is properly made. Of course it is essential that the lens should be placed quite centrally in the bowl; and it is in this respect that the adjustment of burning recorders mostly fails. It is a very common thing to find, even when the lens fits the bowl it occupies, that it is not central, but is either too near to one side, or too high or too low, and such errors often affect the trace. Generally the lens is placed upon a pillar, which is not attached to the bowl, but is separately fixed to the base, and there is no ready means of adjusting this pillar if it is out of position. In another form of the instrument the lens is held between two screws, which grip it at opposite points; but here there is a great liability for it to slip, and an error so caused is not easily set right, especially when the instrument is fixed out of doors.

As a means of avoiding these difficulties, and to ensure at all times a proper position for the lens, I have suggested a modification of the bowl which is illustrated by a model I have upon the table. Here the lens is carried upon a cup, attached to a bracket which forms part of the bowl itself, and therefore cannot be shifted. This cup is fixed in such a position that the centre of a spherical lens of a given diameter, resting upon it, would be the centre also of a great circle of the bowl. The bowl is further provided with a movable adjustment by which it can be readily set to the latitude of the station more accurately, and much more easily, than by the rather clumsy method of tilting the base, which is the plan hitherto most generally adopted. I have been assured that a bowl made with these improvements need not cost more than one made according to the pattern at present in use.

I would suggest that in future all burning recorders should comply with the following specification: The lens should be of crown glass; its diameter, 4 ins.; weight, 3 lbs.; colour, white, or of a yellowish tint, but not green; focal length, from 0·86 in. to 0·88 in.; and that the diameter of a great circle of the bowl should be 5·78 in., which will allow of the use of a card two-hundredths of an inch thick. In this case one hour of the time-scale upon the equinoctial (straight) cards will be 0·75 in. long, which is the scale adopted by the Meteorological Office; and it should be kept in mind that if the time-scale of the card is too open for the bowl in which it is used the record will be too small, and, *vice versa*, if the time-

scale be too contracted for the bowl the record will exceed the truth. It is not improbable that the discrepancies observed in some recorders may be, to some extent at least, due to the use of cards carrying a time-scale unsuited to the diameter of the bowl.

It ought not to be necessary to point out the need for an unobstructed exposure from sunrise to sunset; nor for an accurate adjustment of the instrument as regards latitude and meridian. It may be well, however, to refer to the necessity for keeping the lens clear from snow, and especially from hoar frost, by which the passage of the sun's rays is often obstructed, particularly in the early hours of a winter day, and to which the loss of some hours' trace is occasionally due.

The following is a simple plan for testing the centrality of the lens in the bowl: Cut out of a piece of thin card a circle, the diameter of which is that of the lens plus twice its focal length; out of the centre of this circular piece of card cut another circle of the exact diameter of the lens, and then slip the ring of card thus formed over the lens, so that it shall divide it into two equal parts. If the lens, with the ring upon it, is now placed upon the pillar any error in the position of the pillar may be readily detected by noticing how the ring fits the bowl; it ought to just touch its surface all round, and by turning the lens about upon the pillar all parts of the bowl may be tested.

The tabulation of the curves has been already spoken of, and I would now strongly insist upon the adoption of the broad rule recommended by the Meteorological Office, namely, that in the case of strongly marked burns the measurement should not include the penumbra, although it may take in all the really charred portion of the card; but that with weaker burns the whole of the discoloured card should be included, with the proviso, however, that the discolouration shall always be obvious, and not so faint as to involve discussion as to its actual existence.

Capabilities of the Recorder.

Before concluding this portion of my paper, I may be allowed to give the results of an inquiry, based on the records of five stations, as to the nearest approach of the trace to the actual times of sunrise and sunset. In such an inquiry it must always be remembered that, in the absence of special precautions on the part of the observer, there is a possibility of the card having been placed in the bowl with the noon line not strictly in the meridian of the instrument, and therefore a few minutes' error in either direction is possible; indeed a case has been met with in which, if the card could be believed, the record continued for eight minutes after the sun was below the horizon!

The stations were selected mainly on account of their latitude, and the recorder at each place is believed to have a perfectly clear horizon.

DEERNESS, ORKNEY.—The closest approach of the trace to sunrise during seven years was 24 minutes in January 1896, 25 minutes in August 1892, and 26 minutes in February 1891 and February 1893. There were several instances in the seven years examined in which the record began not later than from 30 to 40 minutes after the time of sunrise.

The latest record was up to 12 minutes of the time of sunset in February 1895. There is no doubt as to the time shown by the trace,

but it is possible the card may have shifted in the bowl, and therefore I do not think this entirely reliable. In December 1891 trace was recorded up to 21 minutes of the time of sunset, and in August 1893 to 27 minutes, and these are probably correct.

STORNOWAY.—In March 1895 the record began 18 minutes after sunrise, and in October 1891 and in April 1892 it began 22 minutes after sunrise. In December 1891 it was continued up to 15 minutes of the time of sunset; in August 1890 to 17 minutes; and in November 1891 to 20 minutes before sunset.

DOUGLAS, ISLE OF MAN.—In December 1894 the trace began 17 minutes after sunrise; and in August 1892 it continued up to 13 minutes of the time of sunset. In August 1893 it continued up to 15 minutes of sunset.

GELDESTON, NORFOLK.—Thirteen minutes after sunrise is the earliest record here, in February 1887. In August 1881, and again in December 1886, the trace began 19 minutes after sunrise; and in October 1881, and February 1883, at 20 minutes after sunrise. It continued up to 14 minutes of the time of sunset in February 1887; 15 minutes in July 1888; 18 minutes in December 1886, and again in February 1887; to 19 minutes of sunset in February 1882; and to 20 minutes in February 1887.

JERSEY.—The closest approach to sunrise here was 13 minutes in February 1894; 14 minutes in October 1893; 15 minutes in February 1891; and 17 minutes in February 1891, and February and October 1895. The trace was continued up to 8 minutes of the time of sunset in July 1892; 10 minutes in February 1896; 12 minutes in August 1893; 13 minutes in March 1891, and in July 1892; and up to from 14 to 20 minutes of sunset on no less than twenty other occasions during the past seven years.

The longest duration of sunshine in any one day, which I have been able to find in the same records of the five stations named above, are as follows:—

STORNOWAY.—92 per cent of the possible total, May 10, 1891.

DOUGLAS.—92 per cent of the possible total, February 27, 1893.

GELDESTON.—94·5 per cent of the possible total, May 30, 1881; 93 per cent of the possible total, May 22, 1881, February 11, 1883, and February 8, 1887.

JERSEY.—94·5 per cent of the possible total on June 23, 1896.

It is worthy of remark that the majority of these records were obtained in the month of February.

These figures are, I think, sufficient to show the capabilities of the Campbell-Stokes instrument, and to prove that it is competent to register all sunshine to which the term "bright," used as defined above, can justly be applied. There is no doubt that a properly adjusted instrument can, under favourable conditions of atmosphere, register sunshine up to 15 minutes of the time of sunrise and sunset.

B. *Jordan Recorder.*

I now pass to the photographic recorders.

I have already pointed out that with these instruments it is far less

easy to decide what is to be considered as the minimum indication of "bright" sunshine than it is with the Campbell-Stokes records; and this is a distinct disadvantage which the photographic records possess. It seems to be perfectly clear that until some proper understanding has been arrived at as to the degree of sensitiveness the papers should possess, the amount of washing they should undergo, and the minimum intensity of colour ultimately to be accepted as "trace," it will be hopeless to expect strictly comparable results from different observers.

The difficulty does not appear to be insuperable. Possibly if a much more sensitive paper were employed—one which could be depended upon to give, when the sun shone with sufficient intensity for its heat rays to discolour the Campbell-Stokes card, a discolouration of the paper sufficient to be still plainly perceptible when the trace had been "fixed," the difficulty might disappear, and the records of the two types of instrument more closely agree.

I have used in the recorder Ilford "Printing Out" paper, and have obtained with it, in one box, a picture of neighbouring objects illuminated by the sun, at the same time that a sun trace was being made in the other. The picture was distinct but faint, and it disappeared entirely in the soda bath. The sun trace was good and sharp, and although it too lost a good deal of depth in "fixing," it remained a good trace; whilst a small portion of it, taken about an hour and a half before sunset, and when the sun was shining through cirrus cloud, although it became weak in colour, was yet perfectly distinct and unmistakable. When this paper was removed from the box there was a certain amount of discolouration, due to diffused light, but this quite disappeared in the soda bath. No toning bath was used. I have not had sufficient experience to warrant me in recommending this or any other kind of paper, but as far as I have been able to ascertain it appears to me that a paper more sensitive than the ferro-prussiate, or cyanotype, would be an advantage.

The photographic recorder is cheaper than the Campbell-Stokes recorder, and the cost of its maintenance is also less; there is no lens to get out of focus, and the management of the instrument is quite as simple as the management of the Campbell-Stokes; if therefore some means could be devised for overcoming the difficulty respecting the trace the use of the instrument might be recommended with a good deal of confidence. At present, with the uncertainty attaching to the value of the photographic result, and knowing the widely different constructions which observers place upon the curves, I cannot avoid feeling some amount of uncertainty as to the value of the records.

The loss of colour in the trace by "fixing" is without doubt a serious drawback; but, as the result of experience, it has been found very unsafe to tabulate the traces before this has been done, and therefore it appears to be an evil which must be put up with in order to avoid others even greater. The time required for fixing is however much less than is, or used to be, recommended, and three or four minutes' washing appears to be quite sufficient, and probably less would suffice if the water was slightly acidulated.

ADDENDUM.

Supposed Deterioration of the Greenwich Recorder.

In the "Report of the Astronomer-Royal to the Board of Visitors" for 1897, the following passages appear with reference to the Greenwich sunshine recorder :—

The sunshine recorder is retained in its altered position on the roof of the Octagon Room, about 50 feet above the ground. On December 24, 1896, it was pointed out by Mr. Marriott that the record obtained was less than that at Bunhill Row in the City. It was suspected that the deficiency was due to the opacity of the glass globe, and on January 1, 1897, a globe of much clearer glass, presented to the Royal Observatory in 1881 by the late Mr. Campbell, was substituted. The discarded ball was mounted on the old Campbell recorder by the side of the Campbell-Stokes instrument for the purposes of comparison.

The following table showing the yearly totals of sunshine registered at Greenwich, Kew, and Bunhill Row, *seems to indicate that the Greenwich record began to fall off about six years ago, the deficiency, however, not becoming marked till* 1894. [The italics are mine.—R. H. C.]

Yearly totals of sunshine registered at—

Year.	Greenwich.	Kew.[1]	Bunhill Row.	Percentage at Greenwich, Kew = 100.
	hrs.	hrs.	hrs.	
1887	1407	1592	1083	88
1888	1068	1157	911	92
1889	1156	1205	965	96
1890	1255	1405	1158	89
1891	1222	1367	1111	89
1892	1277	1519	1265	84
1893	1454	1681	1493	86
1894	1052	1351	1156	78
1895	1227	1592	1300	77
1896	1016	1436	1136	71

[1] These measurements were made at Kew.—R. H. C.

The following table exhibits the results of four months' comparison of the old and new balls, and shows clearly that the old ball is defective :—

1897.	New Ball.	Old Ball.	Excess with New Ball.
	hrs.	hrs.	hrs.
January . .	19·8	10·8	+ 9·0
February . .	34·1	24·2	+ 9·9
March . .	123·4	101·7	+21·7
April . .	144·7	124·8	+19·9

The suggestion made here that the opacity of the old ball is a condition which has been gradually developed during the past few years, is one which, if it should prove to be correct, would constitute a grave objection to the use of burning recorders, because in dealing with their records the possibility of some such change having occurred would always have to be taken into account. Of the reality of the opacity no doubt can exist after a study of the figures in the second table, assuming, of

course, as is no doubt the case, that the lenses fit the stands in which they are now placed; but in view of the importance of the point raised it seemed to me desirable to see whether or not the figures quoted were capable of any other explanation than that suggested.

I have tried to get all the information I could upon the subject, and there seems to be no doubt that certain qualities of glass *may*, under given conditions, change in some such way as this is supposed to have done.

Glass is formed by a fusion of silicious and alkaline matters, and it may consist of one or more salts which are silicates, with bases of potash, soda, lime, oxide of iron, aluminium, or oxide of lead; in any compound of these one of the bases may be substituted for any other, provided only that at least one alkaline base be retained. Glass which has too much alkali in its composition gradually attracts the moisture of the air, and loses its lustre and polish, becoming more or less dull on the surface; and a glass composed of silica and alkalies alone, without lime, will not resist the action of water; but the harder a glass is, the less is it liable to alteration by the action of either atmospheric or chemical agents. Then again, the power of glass to resist the action of these agents depends to some extent upon the amount of heat used in its manufacture, the higher the temperature to which the fused mixture is raised the greater being the resisting power of the glass; and considerable differences are to be found in glasses formed of exactly the same constituents, but subjected to different degrees of heat in their manufacture. If, however, glass is made to undergo frequent and large variations of temperature, it becomes more brittle, and its surface becomes granulated, and consequently less transparent.

Glasses containing lead are liable to become opaque, and iridescent, upon exposure to air in which sulphuretted hydrogen is present, owing to the oxide of lead becoming converted into a sulphuret; and the more lead there is in the glass the quicker does this change take place.

Crown glass, of which the lenses should be made, consists of silicic acid, 63 parts; soda, 22 parts; lime, 12 parts; alumina, 3 parts.

Flint glass contains, as a rule, silicic acid, 45 parts; potash, 12 parts; oxide of lead, 43 parts.

A potash glass, *i.e.* a glass containing potash in its composition, is more apt to be affected by moisture than a soda glass, because of the higher hygrometric properties of the potash; and the presence of lime in the glass, whilst it increases somewhat its density, increases its hardness and lustre also; and on both these grounds crown glass lenses are to be preferred to flint.

If therefore the lens in question is of flint glass and contains an excessive quantity of potash; or if it contains much lead, and the atmosphere in the neighbourhood of the observatory is liable to be charged with sulphuretted hydrogen, it is quite reasonable to suppose that a change in its clearness may have occurred gradually, in the way suggested by the Astronomer-Royal.

But in that case, so far as I can learn, the experience is unique as regards sunshine recorder lenses; and therefore before finally accepting the explanation offered I thought it would be well to see whether the admitted facts could not be satisfactorily explained in some other way.

As I understand the matter, there is no *direct* evidence of such a

change as is suggested having occurred; attention was first called to the appearance of the lens by the fact being noticed that the Greenwich record of sunshine was less than that of Bunhill Row, and no one is able to say, positively, that the lens was ever different from what it is to-day.[1]

I have therefore prepared a table, which I now give, showing the differences between the yearly totals recorded, since the year 1883, at Greenwich, Kew, and Bunhill Row, expressing them as percentages of the totals at Greenwich.

TABLE VII. — YEARLY TOTALS OF SUNSHINE RECORDED AT GREENWICH OBSERVATORY, KEW OBSERVATORY, AND AT BUNHILL ROW, CITY, DURING THE YEARS 1883-1896.

Year.	Total recorded at:			Differences:		
	Greenwich.	Kew.[1]	Bunhill Row.	G.-K.	G.-B.R.	K.-B.R.
	hrs.	hrs.	hrs.	%	%	%
1883	1238	1516	974	−22	+21	+36
1884	1115	1311	928	−18	+17	+29
1885	1262	1437	1018	−14	+19	+29
1886	[2]1228	1436	1003	−17	+18	+30
1887	[3]1407	1566	1083	−11	+23	+31
1888	1068	1129	911	− 6	+15	+19
1889	1156	1217	965	− 5	+17	+21
1890	1255	1395	1158	−11	+ 8	+17
1891	1222	1395	1111	−14	+ 9	+20
1892	1277	1544	[4]1265	−21	+ 1	+18
1893	1454	1685	1493	−16	− 3	+11
1894	1052	1368	1156	−30	−10	+15
1895	1227	1592	1300	−30	− 6	+18
1896	1016	1436	1136	−41	−12	+21

[1] These measurements were made at the Meteorological Office.
[2] Up to this year Mr. Campbell's first ball was in use.
[3] The use of the ball now found to be defective was commenced.
[4] The support of the lens was discovered to be loose in January of this year; this fault must have been a long time in existence, and was sufficient to allow the lens to get somewhat out of focus.

From these figures it will be seen that in 1883, when the first Campbell lens was in the instrument, the difference between Greenwich and Kew was greater than it was in 1893; and in 1889, after the now defective lens had been three years in the instrument, the difference between them fell to only 5 per cent. Indeed the difference does not show any remarkable increase until 1894, when suddenly it almost doubles itself, and then after keeping again stationary for two years, increases, just as abruptly, by one-third.

Now is it not reasonable to suppose that if the cause of the difference was a growing opacity of the lens, as suggested, it would have begun to show itself almost from the first, by a difference increasing more or less regularly from year to year? Instead of this, however, for fully half the period of its use the differences give no such indication of any fault.

Before finally accepting the deterioration theory, therefore, there are two points to which attention may be directed as tending to account for

[1] See footnote on p. 24.

at least part of the difference between the Greenwich and Bunhill Row records: first, the Greenwich record may have been reduced by the fact that during the period in question the instrument was placed at a much lower level than it now occupies, and that, in addition to the existence of many rather high and growing trees at no very great distance to the eastward,[1] new buildings were being erected to the south of it; and secondly, the Bunhill Row record was undoubtedly improved in 1892, when a fault was discovered in the instrument, which must have tended to reduce its records up to that date. The pillar which carries the lens was found to be so loose that it could be moved sufficiently to seriously affect the focus of the sun's image upon the card, and such a movement was always possible whenever the card was changed. This was put right in January 1892, and the record of the instrument from that date agrees better with Kew, whilst it is also the time when the fault in the Greenwich lens is supposed to have begun to develop.[2]

I cannot conclude this report without acknowledging my obligations to Mr. Dowson, F.R.Met.Soc., for his large share in the work; and also to Messrs. Thompson, Call, and Powers, of the Meteorological Office, for a great deal of valuable assistance rendered to me from time to time in preparing my report.

[1] In the *Greenwich Meteorological Observations* for 1894, p. liv., an interruption of the record caused by trees to the east and south-east is mentioned.

[2] Since the above has been in type I have had an opportunity of both seeing the lens in question, and of learning more particularly its history from Mr. Nash, the Superintendent of the Meteorological department of the Observatory. The lens is unquestionably defective, and its surface is covered with an infinite number of minute reticulated markings, which give it a "milky" appearance, and render it only semi-transparent; and further, Mr. Nash informed me that he is confident that the glass was clear when the lens was first put in use, thus correcting a misapprehension I had previously been under. Mr. Nash also pointed out that until the instrument was shifted to its present position it was quite close to the cowl of a ventilating shaft, which continuously discharged into the air a large amount of gases, the products of combustion from the lamps, etc., in the magnetic chamber, above which it was placed. These facts would therefore seem, first, to make it certain that the deterioration has taken place gradually, as suggested by the Astronomer-Royal; and secondly, to make it probable that sulphuretted hydrogen, acting upon lead in the glass, may have been the active cause of the deterioration.

DISCUSSION.

The President (Mr. E. MAWLEY) said that this report had been drawn up at the request of the Council, and that great credit was due to Mr. Dowson for his careful working of the two recorders for twelve months without a single break, as well as to Mr. Curtis for tabulating and discussing so admirably their respective records. He considered some credit might also be claimed by the Society for having through its Council instituted the comparisons. Previous to the appearance of the report much uncertainty existed as to how far sunshine recorders might be relied upon to give comparable results. But now we are assured that, provided certain simple conditions as to the exposure of the instrument and the measurement of the traces be complied with, the Campbell-Stokes instrument at all events might be regarded as giving comparable records. This was a great step gained, and was after all far more important than whether this particular instrument recorded all the sunshine that some considered a sunshine recorder should do. He was surprised to find that the Jordan pattern recorded if anything rather less sunshine than the Campbell-Stokes, as he had always

understood the former to be the more sensitive of the two. He could not follow the author's reasoning as to the defective Greenwich ball, for after seeing it on visitation-day at the Royal Observatory, he was at a loss to understand how a ball of such opacity, if then in its present condition, could have been set up in 1884 to replace the bright one provided by Mr. Campbell, and now again in use at that observatory. He himself, when commencing sunshine observations, had been fortunate enough to secure a ball similar to those then being supplied to the Meteorological Office. That this ball showed no signs of deterioration was evident from the fact that, although it had been in use nearly twenty years, it gave in June last a longer trace than on any previous day since it was set up at Berkhamsted thirteen years ago.

Mr. W. ELLIS said that, so far as he knew the facts, the paper gave an excellent account of the history of the subject. He also considered that the directions in regard to interpretation of the Campbell-Stokes record were practical and good. Of the Jordan record he was unable to speak, having little acquaintance with that instrument. He wished principally to say a little about the Greenwich record. Mr. Campbell, in 1876, gave a sunshine recorder to the Observatory—a glass sphere in a brass bowl—and a daily record was at once commenced, and continued until December 1886. This instrument was in January 1887 superseded by one on the Campbell-Stokes pattern, simply in order to render the record more strictly comparable with those of stations under the Meteorological Office, the new instrument being obtained through the intervention of the late Mr. Lecky, who was understood to be a properly accredited person. On February 6, 1896, the Campbell-Stokes instrument was removed from the position it had till then occupied, on the roof of the Magnet House, to the roof of the old Flamsteed building, a change made because of the building operations in the south ground. Towards the end of the same year, attention having been called to the diminishing amount of the record, the sphere of the Campbell-Stokes instrument was at the end of the year replaced by one given to the Observatory by Mr. Campbell in 1881, the defective sphere being transferred to the old Campbell bowl for further comparison. He wished to show in two ways how the Campbell-Stokes record, at first efficient, had in late years fallen off. When brought into use in 1887, the instrument was compared through one year with the Campbell instrument (previously in use) and found to give generally a record in excess of that by the latter, showing that the Campbell-Stokes instrument was not at first faulty. And up to 1893, when he retired from the Observatory, he could say that there was no apparent falling off, nothing really to attract attention. He exhibited curves, one for each month, indicating for Greenwich, from 1877 to 1896, the progress from year to year of sunshine as recorded, and cloud as observed, the comparisons showing that the sunshine record continued satisfactory until the last three or four years, then falling off. He showed also curves, one for each month, 1886 to 1896, in which the records at Greenwich, Kew, and Bunhill Row were compared, indicating similarly falling of in the later years. The Greenwich record would appear to be trustworthy until about 1892 or 1893, then uncertain until the end of 1896. But in 1897, after change of the glass sphere, it became again efficient. It is known that glass will deteriorate. Mr. Curtis admits this, but doubts whether it is so in the present case. The apparently abrupt change at a certain epoch, of which he speaks, seems to arise from discussing yearly totals. The curves he (Mr. Ellis) exhibited also indicate that the opacity did not, as suggested, show itself from the first. The influence of surroundings, a supposed increase of residential and manufacturing buildings and trees, combined with the circumstance of the instrument having been previously at a lower level than now, is suggested as causing diminished register. To this there is one sufficient answer. It was on February 6, 1896,

that the Campbell-Stokes instrument was removed from the lower to the higher level, and during the remainder of that year the deficiency of register at the higher level continued as before. But the changing of the glass sphere for another at the beginning of the year 1897 restored the register to its normal condition. Thus it was simply a question of the sphere employed, and not its position or surroundings. Mr. Curtis had noted numerous instances of record having been obtained unusually near to sunrise and sunset in or towards the winter season. He (Mr. Ellis) had remarked the same thing at Greenwich (see *Quarterly Journal*, vol. vi. p. 133). This is interesting as indicating greater transparency of the atmosphere at such times, especially as regards winter when the sun's altitude increases more slowly than at other seasons. The instances given for Jersey are remarkable at all periods of the year, indicating record frequently when the altitude of the sun would not be more than 2°. It might have been interesting to make the comparison between the Campbell-Stokes and Jordan recorders for hours through the day, but this would of course have involved a good deal of work.

Mr. W. MARRIOTT said that for some time he did not fully understand the method of adjusting the Campbell-Stokes recorder; and he believed that the observers did not understand it. He was glad that the Council had instituted this comparison, and that the results were so satisfactory. In the earlier issues of the *Meteorological Record* it had been the custom to print the results obtained from the two recorders together in one table; but since it had been so generally recognised that the Campbell-Stokes instrument recorded sun-*heat*, and the Jordan instrument sun-*light*, the results had been printed in separate tables. The Campbell-Stokes instrument was very simple when once the method of adjustment was understood; but it was to be regretted that the makers did not send out the recorders in good adjustment. As it was, it often happened that the instruments were received by observers who were totally ignorant as to how they should be set up. It was imperative that the ball should be precisely in the centre of the frame. A rough test to prove this was to pass a sovereign round between the ball and the card. The "universal pattern" of the Campbell-Stokes recorder was liable to the serious and troublesome defect of the ball slipping down, through the packing wearing away by exposure to the weather. The cheap pattern of the Jordan recorder was not to be recommended, as it was so constructed that it would soon perish from exposure to the weather. He had also found that the ordinary Jordan recorders were in some places much acted upon by the weather, the scale being obliterated, and the screws corroded in such a manner as to render it difficult to readjust the instrument. In the ordinary Campbell-Stokes recorder this difficulty did not arise, as the pedestal and the frame were both readjustable by means of screws at the back of the slate slab. From Mr. Curtis's report it appeared that four skilled tabulators in the Meteorological Office did not agree in their measurements of the traces; and this being so, it was not to be wondered at that ordinary observers did not always tabulate the traces in the same way. A very important point to consider with regard to sunshine recorders was the difficulty of maintaining a good exposure. The recorders at several stations, which a few years ago commanded a clear horizon, had since become seriously interfered with by the growth of trees and shrubs. In illustration of this Mr. Marriott showed some lantern slides of the Rousdon Observatory, in which the growth of trees during several years was very marked. Mr. Curtis had mentioned instances in which the Campbell-Stokes instruments had begun to record within 13 minutes after sunrise, and had continued to record up to within 8 minutes of sunset. This was saying very much for their efficiency, considering the very small angle at which the sun's rays would fall on the recorder at those times. Mr. Ellis had informed him (Mr. Marriott) that the times that will

elapse before the sun, after rising, will attain an altitude of 5° (that is, the interval from the sun's centre being *apparently* in the horizon to being *apparently* at an altitude of 5°) are as follows :—

	Lat. 50°	Lat. 54°	Lat. 58°
	h. m.	h. m.	h. m.
Summer solstice . .	0 41	0 47	0 57
Winter solstice . .	0 45	0 54	1 11
At equinox . .	0 34	0 37	0 41

Owing to refraction the times are increased from what they would otherwise be, by from 3 to 5 minutes, according to latitude and season. If therefore trees in the east should rise to an angle of 5°, the instrument could not begin to record till about three-quarters of an hour after sunrise ; but as under favourable circumstances the instrument should begin to record within 15 minutes after sunrise, there would be a loss of half an hour's sunshine. He (Mr. Marriott) believed that the reason why less sunshine had been recorded at Greenwich than at Kew was partly owing to the fact that when the recorder was on the roof of the Magnet House, there were some trees to the east and south-east which made an angle of about 11°, while there were also trees to the south-west and west.

Mr. J. KENWARD said he perfectly remembered assisting Mr. Campbell in the construction of the first glass ball, and the trouble they had taken in getting perfection. It was made of the same glass as is used in lighthouses, the refracting index being 1·51. It was of perfect lens quality, and the focus was remarkably short. It was tested later, and no deterioration had taken place. He thought that our lighthouses were a proof of the quality of the glass. The late Prof. J. Tyndall, F.R.S., and himself, had tested glass that had been in the Longships' lighthouse for forty years, and had found it tinted yellow and blue, which was due entirely to the sun's action ; and it was extremely probable that the defect in the Greenwich ball was due to the same cause. The four-inch ball was simple and good, and he was pleased to see it holding its own.

Mr. W. G. DAVIS said that, in the Argentine, glass spheres had remained perfect for ten years. At stations at the foot of the Cordilleras the estimated sunshine was from 70 to 75 per cent of the possible duration, while at those in the region of the great rivers the estimated sunshine was from 56 to 58 per cent, and in the Pampas region from 62 to 66 per cent.

Mr. J. B. JORDAN said that he had been much interested in hearing Mr. Curtis's report of the experiments, they had doubtless been conducted with a great deal of care and with every desire to test thoroughly the capabilities of both instruments. He would like to make an observation with reference to the tabulation of the results of the photographic recorder. He thought it a mistake to put any limit on the reading of the trace by disregarding any portion of it, however faint, anything that is visible in the form of a trace should, in his opinion, be taken as a record of bright sunshine. The photographic recorder cannot register too much bright sunshine, the effects on the sensitised paper being produced only by direct rays when strong enough to throw an image of the aperture, through which they pass into the instrument, on the surface of the chart, and however faint an indication it ought to be recorded in the tabulation. Further, it should be remembered that in the process of washing the charts for the purpose of fixing the results, a very faint trace is liable to become even fainter, which is another reason for including all the indications that are visible. He attributed the difference in the results of the two instruments mainly to the omission from the tabulation of some of these faint traces. In similar experiments made at the Kew Observatory in 1887, the Campbell-Stokes and the Jordan recorders were found to give practically

identical results, the difference between the two records being less than 1 per cent, a very different result to that obtained by the experiments at Geldeston, and he could only account for the wide discrepancy in the manner described. With reference to the remark made by Mr. Marriott that in visiting one of the stations, it was found that the twin recorder there used had been so rusted up by the weather that it could not be adjusted, Mr. Jordan observed that the instruments ought not to require readjusting, after being once fixed to suit a particular station. And he suggested that it would be convenient if all sunshine recorders supplied by the makers could be properly adjusted to the latitude of the station where they are to be used. When once fixed securely, the Jordan twin recorder is not liable to get out of adjustment.

Mr. F. GASTER said that, looking at the wide scope of the paper, he thought that the title "Sunshine Recorders and their Indications" would be more appropriate than the one appearing at present. He had not found time to go into the details of the work, but it struck him that the restrictions under which Mr. Curtis's assistants had been placed in making the measurements for Table III. had not been completely shaken off when making the measurements for Table IV. He (Mr. Gaster) never knew of such a thing as sunshine being strong enough to burn a Stokes' card without making a mark on the photographic chart so strong that it could not be removed by ordinary washing. He would remark, however, in passing, that the original intention of the Jordan recorder was to obtain a record of that faint (as well as the bright) sunshine which the Campbell-Stokes instrument failed to register. This it certainly did at first, when the charts were of a certain degree of sensitiveness, and when the register was measured before washing; but the suggestions of authorities were so strong that at length Mr. Jordan had consented to the measurements being made after washing, in order that the indications might be comparable with those of the burning recorder. No previous set of comparisons had shown that the photographic recorder gave a smaller record than the burner, and the only conclusion he (Mr. Gaster) could come to was that the sensitised paper issued must have been of a quality inferior to that supplied at first. Unhappily there were other reasons for believing that uniformity had not been even nearly assured. Looking, however, at the final conclusions arrived at by Mr. Curtis, it was very satisfactory to find him saying with regard to the Campbell-Stokes instrument, "These figures are, I think, sufficient to show . . . that the Campbell-Stokes instrument is competent to register all sunshine to which the term 'bright' can be applied"; and then to admit that the Jordan recorder, when managed according to certain rules (which rules Mr. Gaster had understood to have been in force for some long time past), would give indications comparable with those of the burning recorder. If those who vend these instruments to the public are not using such care that they shall be absolutely accurate in adjustment for latitude, for concentricity, and for focus, and the sensitised paper of a character so uniform that the records of various years shall be fairly comparable, it is quite time they roused themselves to the serious results which such neglect must bring about. It is useless for men of high scientific attainment to use their best powers in order to supply a well-recognised want, if those who send the work forth to the world do so with defects such as will ruin the results of years of labour.

Mr. F. J. BRODIE remarked that, in looking over Table IV., he had been struck with the fact that, while the annual amounts of sunshine yielded by the two recorders agreed very closely, there was a large difference between the results given for some individual months. Thus, in January, the amount by the Jordan instrument was 21 per cent less, and in December as much as 30 per cent less, than that given by the Campbell-Stokes recorder. Seeing that in these two winter months the record by the burning recorder was, if anything,

below the true value, it seemed clear from the comparison that at this season of the year, at all events, the Jordan recorder was by no means as satisfactory an instrument as could be wished. He was glad to hear that the defect in the Greenwich record was due solely to a deterioration of the glass ball, and not to any error in the exposure of the instrument. The opacity of the glass seemed to be now quite obvious, and it was only to be regretted that its condition had not been detected sufficiently early to prevent so serious a vitiation of the records.

Mr. H. N. Dickson thought the paper an excellent one, and he hoped the Society would continue the discussion of the question. He himself could scarcely accept the results set forth in the paper as final. It was to be regretted that the difference between the records of the two instruments seemed so uncertain; and yet, considering all things, it was almost impossible for them to agree, more especially during the winter months, constructed as they were for seemingly two different purposes—one for the registering of heat, and the other of light. He hoped that the Society would continue the investigation. He thought that comparisons of this kind suffered to some extent by using only monthly and yearly means, thus smoothing over what would otherwise be strongly marked points and differences.

Mr. E. T. Dowson wrote: "The only point that occurs to me is *re* the development of the winter Jordan cards; they needed about half the time under water which the summer ones required, and I thought that the morning and evening records on the same day were affected to a different extent by the water, the one being liable to less dissipation than the other. Four minutes' immersion reduced the length of the morning trace about as much as two minutes under water did the evening trace. I have also given two minutes to both, which produced less effect on the tip of the morning than on that of the evening trace. How far the length of dip affects the faint parts during the day I cannot say, but these facts complicate the matter, and render the Jordan trace less reliable."

Mr. G. J. Symons remarked that many points remained for consideration. With reference to the Campbell-Stokes instruments, nothing had been mentioned with regard to the deposit of hoar-frost, etc., on the ball, or the cleaning it should undergo from time to time; nothing as to the bell-glasses which on the continent were often put over them; and with regard to the photographic patterns, he thought that synchronous records should be obtained with photographic paper of different degrees of sensitiveness.

Mr. R. H. Curtis, in reply to Mr. Jordan, reminded him that in the second measurement of the photographic curves the object had been to include all visible trace, however faint; but even so, the difficulty in deciding what was really "trace" had not been got rid of, as was shown by the differences still existing in the results obtained by the three tabulators; and so long as it was necessary to measure "trace," which differed so exceedingly little in colour from the general tint of the paper, this uncertainty would continue. He was well aware of the danger from the use of means to which Mr. Dickson had referred, but the daily, and in many cases the hourly, differences had been carefully examined, and no evidence could be detected of their being related to any meteorological conditions, nor did they appear to group themselves in any definite manner, and therefore he thought it would suffice to give mean results. He had called attention to the effect of hoar-frost and snow, to which Mr. Symons had referred, and of course it was essential to keep the lens as free as possible from every form of obstruction; but the use of covers of any sort was very objectionable, and the shape, size, thickness, colour, and kind of glass employed for the bell-glass might each tend to vary the result. He had only known of one case in which such a cover had been used in England, and that had long since been discontinued. With reference to Mr. Gaster's remarks, he

might say that since as much as three hours' more sunshine had been registered in one day by the Campbell-Stokes than by the photographic recorder, it was perfectly certain that the sun could burn a card without the photographic sheet being correspondingly marked; on the other hand, there had been many instances in which the reverse had happened. To some extent this may have been due to the degree of sensitiveness possessed by the paper, but he did not think it was so always, and he could only repeat again that it did not follow that the most active chemical action accompanied the conditions most favourable for burning. As Mr. Gaster had referred to previous comparisons, he might remind him that very little is known of the conditions under which some of them were carried out. Whilst in at least one case it is now known that the Campbell-Stokes instrument was entirely out of adjustment, to which cause the result obtained, and which has been a good deal quoted, was unquestionably due. Certainly in the present instance every care had been taken to ensure getting a reliable and quite unbiased trial, and if it is objected that its result as regards the Jordan instrument was affected by the quality of the papers used, it is sufficient to reply that they were the papers issued for the purpose by the makers most interested in supplying good ones, and it is not the least important of the results obtained by the comparison that it has shown that such variations in the records may be looked for as a result of differences in the papers which observers would have no means of detecting.

Dr. S. SUTHERLAND, in a note to the Secretary, said: "I would like to express my gratitude to the author of this interesting paper for throwing light on some points in connection with possible errors in the registration of sunshine by the Jordan photographic recorder.

"As an example of a probable error in recording, I may mention that while collecting statistics in the early part of this year, concerning the climate of British health resorts, I found that Bexhill-on-Sea claimed 2021 hours of sunshine for the year 1896, as registered by a Jordan recorder. This amount is so much larger than that recorded at Hastings and Eastbourne, both of which are only at a few miles' distance, that I doubted its accuracy, and a conversation this evening with Mr. Marriott has confirmed my doubts. I mention this in order to emphasise the necessity of ensuring proper records by every possible means, so that medical men and the public may not be misled by inaccurate reports.

"A few months ago I was told by a well-known manufacturer of meteorological instruments that an individual connected with a health-resort in England, came to him some time ago to order a sunshine recorder to be made, which would register one-third more than the correct ones!"

Mr. W. MARRIOTT, in reply to Dr. Sutherland's note, intimated that, when inspecting the station at Bexhill-on-Sea in July last, he found that it had been the custom to measure the trace from the Jordan recorder without its having been previously "fixed." Consequently, the amount of sunshine was not comparable with that at other stations where the traces were fixed before being measured. Since the above date, the trace at Bexhill-on-Sea had been fixed before being measured; and, in addition, a Campbell-Stokes burning recorder has also been obtained, and is mounted by the side of the Jordan photographic recorder. The sunshine records for Bexhill-on-Sea will therefore now be strictly comparable with those from other stations.

DAILY VALUES OF NON-INSTRUMENTAL METEOROLOGICAL PHENOMENA IN LONDON, 1763–1896.

By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

[Read December 15, 1897.]

In a paper communicated to the Society in June last[1] I gave the results obtained from the reduction of the non-instrumental meteorological observations made in London, or its immediate vicinity, during 167 years, the data there discussed being monthly and annual values. In the present paper I have further extended the inquiry by collecting daily values with the view of defining more precisely the seasonal variation. The daily values, as was to be expected, are subject to great day to day irregularities, so that five-day means were formed (see Table VIII.), from which the graphical curves were constructed. The observations made by Smith from 1713 to 1745 do not appear to be thoroughly reliable, so that they were not utilised. The inquiry was thus restricted to the 134 years, 1763 to 1896. As regards fog, it was considered advisable to confine the period under discussion to the 86 years, 1811 to 1896, during which time the observations were made at Greenwich. It will be seen that even the five-day values are subject to great variability. This will probably disappear to some extent as the period under discussion lengthens. I do not therefore intend to attempt to explain many of the sinuosities in the curves, but merely to point out a few of the more characteristic features in the seasonal variation of the phenomena under discussion.

Thunderstorms.

Thunderstorms being almost wholly confined to the spring and summer months, the period October to March may be disregarded, as the

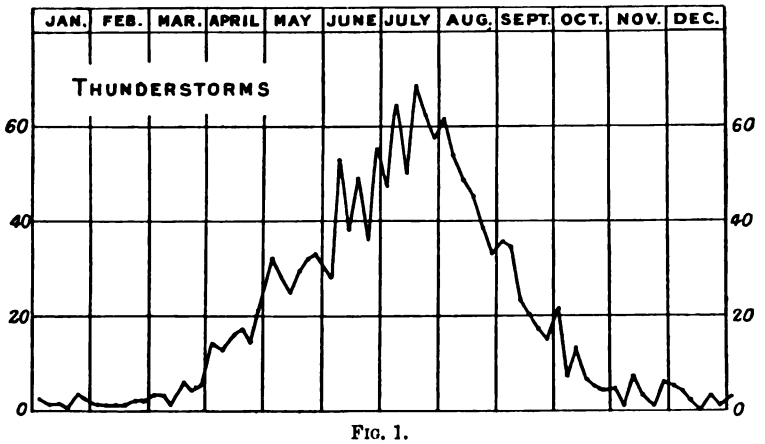


Fig. 1.

values during this time are subject to little variation. Towards the end of March the winter minimum comes to an end, a slight increase being

[1] *Quarterly Journal Roy. Met. Soc.* vol. xxiii. p. 287.

then perceptible; but until the close of April there is no decided rise. The summer frequency may be said to extend from the beginning of June to the middle of August. The absolute maximum occurs from July 14 to 20. A rapid decline sets in at the beginning of August, which practically continues without interruption till the commencement of the long winter minimum in October.

Lightning without Thunder.

This curve is extremely irregular, neither the winter minimum nor the summer maximum being so sharply defined as in the case of thunderstorms. The maximum is very ill-defined, being spread over the four months July to October. The first decided rise takes place in the five-day period, April 21 to 25, a slight diminution occurring in May. The sharp alternations in the five-day groups do not admit of ready explanation,

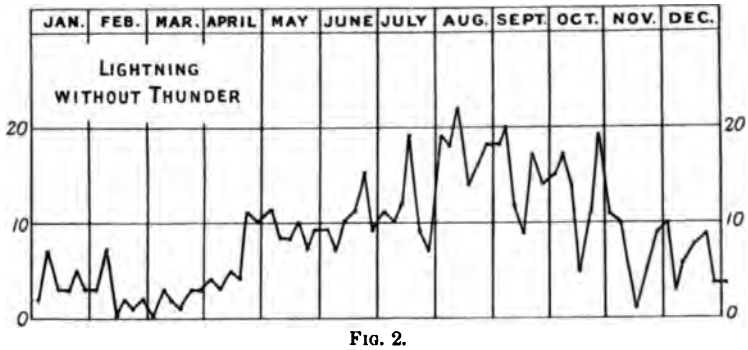


FIG. 2.

and will probably become smoothed out to a considerable degree as more statistics become available. The number increases rapidly after the summer solstice, as is to be expected in a phenomenon which is essentially nocturnal in its occurrence. The maximum occurs in the five-day period, August 9 to 13, but values nearly as high are recorded about the middle of July, the beginning of September, and the end of October. After the autumnal maximum a rapid decline sets in, the minimum embracing the period February 10 to March 2.

Mist and Fog.

During January there is little variation between the five-day values, but a fall occurs towards the close of the fourth week. Fogs diminish rapidly after February 22, and fall with a few interruptions to their annual minimum at the beginning of July. During the autumnal fall of temperature fogs increase rapidly, the rise in the five-day values during the month of September being the most noticeable feature of the curve. This is rather remarkable, as the amount of cloud at Greenwich [1] is at its annual minimum at the time. The maximum is attained in the five days ending October 17. This may be of accidental occurrence, but it may be observed that gales are (for the season) comparatively infrequent during the second half of October, the atmospheric conditions being thus favour-

[1] *Quarterly Journal Roy. Met. Soc.* vol. xxii. p. 170.

able for the formation of fog. Temperature at this time is falling rapidly. The true maximum extends from November 5 to 24, and this not only applies to the number, but also to the density of fogs. During

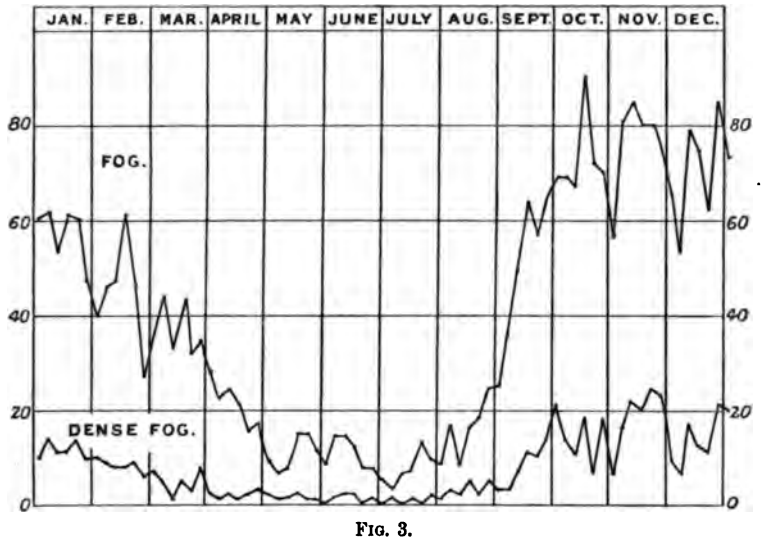


FIG. 3.

the above period no less than 27 per cent of all the fogs recorded were designated "thick" or "dense." At the end of November fogs diminish both in number and density, only 15 per cent being recorded as "dense" in the fortnight ending with December 8. The weather at this time is characterised by strong winds, which are accompanied by mild weather, the autumnal fall of temperature being retarded for a few days. About Christmas fogs again exhibit an increase.

Snow.

Snow showers are at their annual maximum at the beginning of January, but diminish rapidly during the rather stormy weather which usually sets in about the 13th of the month. A secondary maximum occurs at the beginning of March; and as these snowstorms are accompanied by strong winds and a rather low temperature, this may be looked upon as one of the most inclement periods of the year. Towards the close of March snowstorms rapidly diminish, but an increase again occurs from April 11 to 18. It has been found from the reduction of long period observations of mean temperatures for each day of the year, that there is a well-marked retardation in the vernal rise of temperature about the middle of April, which holds good for the greater part of Western Europe. There is thus a greater tendency for snow about this time. After the third week of April snow showers rapidly diminish. Snow perceptibly increases after the middle of November, and continues to do so until the maximum in January. There are, however, slight interruptions in the first and third weeks of December.

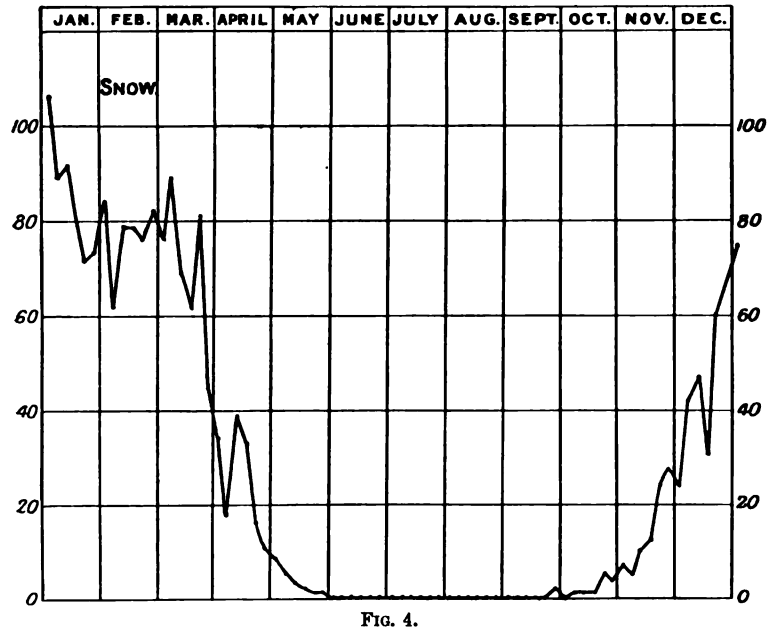


FIG. 4.

Hail.

With the exception of the well-marked spring maximum, which extends from about the third week of February to the middle of May, this curve

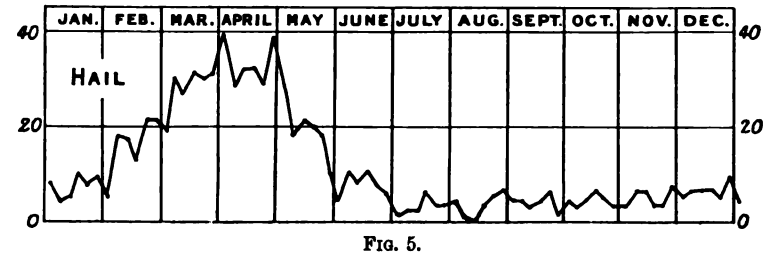


FIG. 5.

is quite featureless. An interesting point, however, is the comparative frequency with which true hail accompanies thunderstorms in June as compared with other months of thunderstorm frequency.

Gales.

Gales are rather infrequent during the cold weather at the beginning of January, but thereafter rise rapidly and attain their annual maximum at the end of the month. A secondary maximum occurs at the beginning of March. Gales rapidly diminish in frequency after the first week of March, which seems to indicate that they are by no means of frequent occurrence at the spring equinox. The annual minimum is not clearly defined, storms being at their lowest at the end of April and beginning of August. Towards the close of September a rapid increase takes place,

which rather supports than otherwise the popular opinion regarding gales at the autumnal equinox. It may be pointed out that the values in September are by no means high as compared with the six months, October to March. The advent of the autumnal equinox may thus be said

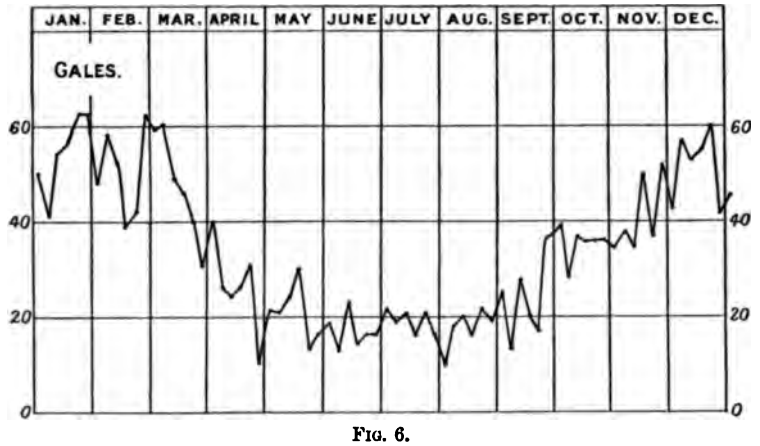


FIG. 6.

to mark the termination of the tranquil summer conditions rather than the commencement of very stormy weather. The comparatively quiet spell experienced from the first week of October till nearly the middle of November is of interest, as is the sharp drop during Christmas week, when the quiet atmospheric condition occasions a good deal of fog.

TABLE I.—NUMBER OF THUNDERSTORMS ON EACH DAY OF THE YEAR IN LONDON FROM 1763 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	...	1	1	1	6	4	9	10	7	6	2	...
2	...	...	...	3	8	3	9	14	4	2	1	2
3	1	...	2	4	6	7	13	11	7	2	...	2
4	1	...	...	4	4	10	8	9	4	1	...	...
5	...	...	...	2	8	15	12	11	4	3	...	...
6	...	...	1	2	6	13	22	11	10	1	...	...
7	...	...	1	2	4	10	13	12	9	...	2	1
8	...	...	...	2	8	7	10	10	6	4	2	1
9	...	1	...	3	8	8	7	7	5	1	...	...
10	1	...	1	4	2	7	10	12	4	3	3	...
11	...	1	1	3	4	5	10	12	4	5	...	...
12	...	...	...	6	4	6	11	10	4	...	1	...
13	1	...	1	2	3	9	5	7	4	...	1	...
14	...	...	...	2	4	11	14	8	4	1	...	...
15	...	...	...	3	10	8	15	9	5	3	...	...
16	...	...	...	4	4	8	15	11	2	1	1	...
17	...	1	...	3	6	11	15	12	5	1	...	...
18	...	...	2	3	4	14	10	5	4	...	...	...
19	...	...	1	6	8	8	13	14	2	1	1	1
20	...	...	1	1	7	7	15	6	1	2	...	2
21	...	...	2	...	6	5	10	6	6	1	...	...
22	...	1	2	3	6	5	9	8	4	1	3	...
23	2	1	...	5	10	7	17	4	5	...	...	1
24	1	...	1	1	5	12	11	11	5	...	1	...
25	...	1	...	5	5	8	16	10	...	2	1	...
26	...	...	1	4	4	13	10	8	3	1	1	...
27	...	...	...	3	9	7	12	3	2	1	1	...
28	1	...	2	4	8	15	7	1	4	1	1	1
29	1	...	...	3	9	12	12	8	3	...	3	1
30	...		2	7	3	8	16	6	6	1	...	1
31	...		1		4		11	10		...		...

TABLE II.—Number of Days of Lightning without Thunder in London from 1763 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	...	...	1	...	5	...	5	2	4	5	2	2
2	...	...	...	...	1	2	2	3	3	5	2	...
3	...	...	...	2	2	3	...	5	4	4	3	...
4	1	1	...	...	2	3	4	5	4	3	2	1
5	1	1	...	2	1	...	2	5	7	3	1	2
6	1	1	...	...	1	...	2	3	3	2	2	...
7	1	1	...	1	2	2	2	1	2	5	2	...
8	3	3	1	1	2	2	2	4	2	3	2	3
9	1	1	...	1	...	3	2	5	4	3	...	1
10	1	...	1	...	3	...	1	5	3	3	...	...
11	2	...	1	...	2	2	...	5	...	3	1	2
12	...	...	1	1	2	3	2	3	3	2	...	2
13	1	...	1	1	2	3	5	4	2	1	...	1
14	...	...	...	1	1	2	4	2	...	1	1	1
15	...	...	...	2	1	5	5	3	2	1	...	2
16	...	1	...	2	4	3	6	4	1	1	...	2
17	1	...	...	...	3	2	3	1	4	1	2	3
18	...	1	1	1	2	...	1	4	1	1	...	2
19	1	...	...	1	1	1	4	4	2	2	1	1
20	1	1	...	...	...	4	3	3	5	4	1	1
21	...	...	...	...	2	2	2	3	5	...	1	2
22	1	...	1	2	...	4	...	3	4	4	2	2
23	...	...	...	4	1	1	2	3	4	3	...	...
24	1	...	1	4	3	4	2	4	6	4	3	...
25	3	...	1	1	1	3	1	4	...	3	2	1
26	1	1	...	4	2	2	2	4	1	7	2	1
27	1	...	...	2	...	1	1	2	3	2	1	...
28	1	...	...	1	3	1	1	4	2	...	1	2
29	...	...	1	...	2	2	2	5	2	2	4	1
30	...		1	3	2	...	3	3	1	3	2	1
31	2		1		1		6	3		4		...

TABLE III.—Number of Fogs on each Day of the Year in London from 1811 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	11	9	3	10	1	3	1	1	7	12	12	13
2	15	9	8	4	3	3	...	1	5	16	12	14
3	10	9	9	5	1	1	2	2	7	9	18	7
4	14	7	6	3	1	...	1	2	7	12	11	9
5	10	8	7	6	3	2	1	6	8	15	15	11
6	17	12	6	6	...	4	...	4	10	15	17	13
7	15	7	8	7	2	2	1	3	4	18	20	8
8	8	7	8	5	3	4	...	...	10	12	18	16
9	10	12	11	2	...	2	1	1	9	13	17	15
10	11	7	12	2	1	3	1	2	10	10	13	20
11	8	8	5	7	2	1	1	1	13	13	16	20
12	14	11	8	7	1	3	2	2	8	17	21	15
13	11	8	6	2	1	4	1	3	15	21	17	17
14	14	13	5	5	2	3	1	1	9	19	16	16
15	6	11	7	3	2	1	2	2	14	15	10	14
16	12	11	7	4	2	1	2	4	9	19	16	13
17	9	14	10	5	6	3	1	3	17	16	18	17
18	16	13	9	4	...	2	...	7	11	14	17	11
19	12	12	14	4	3	5	2	3	13	15	16	10
20	12	8	13	4	3	...	1	4	8	14	12	12
21	12	10	8	6	3	1	...	2	13	16	17	13
22	12	14	9	1	7	2	4	5	12	13	17	21
23	12	8	6	1	1	3	5	5	13	15	18	18
24	11	6	6	5	2	1	3	7	12	13	16	17
25	13	6	3	2	1	2	1	8	15	16	13	16
26	8	5	8	2	4	1	1	2	12	16	11	13
27	11	7	7	4	2	2	2	3	14	10	16	16
28	11	6	6	3	3	...	2	5	18	13	14	16
29	10	(2)	9	3	1	2	4	4	11	12	12	13
30	7		8	5	1	1	3	6	12	13	11	14
31	5		5		1		2	4		7		15

TABLE IV.—NUMBER OF DENSE FOGS ON EACH DAY OF THE YEAR IN LONDON FROM 1811 TO 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2	3	...	1	...	...	...	...	1	4	...	2
2	2	2	2	...	...	...	...	...	1	6	4	4
3	2	1	2	...	1	...	...	...	1	2	5	...
4	3	4	2	...	1	...	...	1	..	4	3	...
5	1	2	2	1	...	...	1	1	1	4	2	...
6	5	...	...	1	...	...	...	...	1	2	2	2
7	2	2	1	...	1	...	...	1	...	2	4	1
8	2	2	2	...	...	1	...	...	2	1	6	4
9	1	3	...	...	...	...	...	1	1	3	3	2
10	4	2	2	...	...	2	...	...	2	4	4	4
11	4	2	...	1	...	...	...	...	...	...	5	6
12	4	2	...	...	1	...	...	...	2	2	5	3
13	2	1	...	...	...	...	...	1	3	6	4	4
14	1	1	...	...	...	...	...	1	...	2	3	1
15	...	2	1	1	...	...	...	...	2	7	4	3
16	...	2	...	1	...	...	...	2	3	2	4	2
17	3	2	2	...	1	...	1	1	3	1	7	3
18	4	1	2	...	...	...	...	1	2	2	4	2
19	3	1	1	...	...	2	...	...	1	2	5	4
20	1	1	...	...	1	...	...	1	1	1	3	2
21	3	1	2	1	...	...	...	...	3	1	5	2
22	2	2	...	...	...	...	...	1	3	1	4	6
23	3	3	...	...	...	...	...	...	1	5	8	4
24	2	2	2	1	1	...	...	2	2	5	6	5
25	5	3	1	...	...	...	...	2	4	2	4	2
26	2	1	...	...	...	...	...	...	2	3	1	4
27	...	...	1	1	1	...	...	...	5	3	2	4
28	3	2	1	1	...	1	2	1	4	2	1	3
29	4	(...)	3	...	...	...	...	...	3	3	3	4
30	2		2	1	...	...	1	1	4	1	1	3
31	...		1		...		...	...		...		6

TABLE V.—NUMBER OF TIMES SNOW FELL ON EACH DAY OF THE YEAR IN LONDON FROM 1763 TO 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	22	19	16	11	1	...	...	...	...	...	1	6
2	22	22	16	10	1	...	...	...	...	...	1	6
3	22	13	20	6	2	...	...	...	...	...	...	11
4	15	13	13	4	2	...	...	...	...	...	1	6
5	25	13	8	3	2	...	...	...	...	...	2	8
6	22	17	19	2	1	...	...	...	...	...	1	11
7	13	10	13	1	3	...	...	...	...	1	1	8
8	20	9	17	4	...	...	...	...	...	...	2	8
9	19	13	23	5	...	...	...	...	...	...	1	10
10	15	13	20	6	1	...	...	...	...	...	3	12
11	22	23	16	9	...	...	...	...	...	...	3	9
12	23	9	19	9	...	...	...	...	...	1	...	5
13	15	21	12	6	...	..	...	...	...	1	2	5
14	12	12	12	9	1	...	...	...	...	...	1	5
15	19	14	13	6	2	...	...	...	...	...	3	7
16	16	13	13	9	2	...	...	...	...	...	6	9
17	13	15	13	6	...	...	...	...	...	...	6	15
18	16	19	9	8	...	...	...	...	...	1	4	10
19	17	17	13	4	...	...	...	...	...	...	5	15
20	17	15	13	6	...	...	...	...	...	2	5	10
21	14	19	4	5	...	...	...	...	...	1	4	11
22	14	15	17	2	1	...	...	...	...	1	5	15
23	15	15	16	1	...	...	...	...	...	...	2	8
24	15	12	17	6	...	...	...	...	1	1	3	12
25	13	18	14	2	...	...	...	...	1	1	8	14
26	15	16	17	2	...	...	...	...	...	1	10	18
27	13	16	12	3	1	...	...	...	...	1	6	22
28	18	16	12	1	...	...	...	...	...	1	2	19
29	12	(4)	7	4	...	...	...	...	...	2	4	9
30	15		7	...	...	...	...	...	...	3	6	12
31	17		7		...		...	...		...		13

TABLE VI—Number of times Hail fell on each Day of the Year in London from 1768 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	...	1	6	7	4	3	...	1	2	...	1	1
2	...	...	4	6	6	...	...	1	...	1	1	2
3	2	1	7	11	6	...	1	...	...	...	2	1
4	4	1	2	6	6	1	...	...	...	1	1	1
5	2	2	1	9	6	3	1	1	1	1	1	1
6	...	2	5	3	3	2	...	...	2	1	1	1
7	...	5	3	3	2	5	1	...	1	...	1	1
8	1	5	13	9	5	...	...	...	...	1	1	2
9	1	4	4	7	6	...	...	...	2	...	...	...
10	2	2	5	7	2	4	...	...	...	...	3	2
11	...	4	5	8	3	1	...	...	1	2	1	1
12	2	2	6	14	2	1	...	...	...	1	...	1
13	...	3	4	4	5	1	1	...	1	1	1	2
14	1	6	5	2	3	1	1	1	...	1	1	1
15	2	...	7	4	8	4	3	1	2	2	...	1
16	1	4	5	5	5	3	...	...	1	1	1	1
17	1	2	4	8	4	1	2	1	...	1	...	...
18	1	3	7	4	3	2	1	...	2	1	...	1
19	4	4	7	8	4	...	...	...	1	2	1	2
20	3	2	4	7	4	1	1	1	2	1	1	1
21	1	3	9	1	2	...	1	1	1	...	1	1
22	2	5	8	7	4	1	...	1	...	1	4	2
23	1	6	7	8	4	3	1	2	1	...	1	5
24	3	5	7	11	4	2	...	1	...	1	...	1
25	1	6	2	2	4	...	...	2	...	1	2	...
26	2	1	6	9	3	...	...	1	...	1	...	1
27	...	3	6	8	...	2	1	1	...	...	...	...
28	5	5	6	8	1	2	1	1	1	2	...	...
29	1	1	6	6	3	2	1	1	1	...	4	1
30	1		9	7	3	...	2	1	1	...	...	2
31	2		4		1		...	...		...		1

TABLE VII.—Number of Gales on each Day of the Year in London from 1763 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7	12	15	9	7	3	4	1	4	6	8	6
2	10	10	11	11	5	6	6	1	3	8	9	18
3	14	5	16	9	3	2	7	3	1	6	9	11
4	9	6	7	7	1	6	3	2	...	5	7	11
5	10	9	13	4	5	3	4	6	3	3	4	8
6	8	8	12	5	6	2	3	2	4	5	9	9
7	6	16	11	7	4	3	3	3	5	10	4	17
8	7	13	12	6	2	2	5	5	2	8	4	12
9	7	12	15	5	5	3	4	5	6	9	6	11
10	13	9	10	3	4	5	3	4	6	9	8	8
11	8	14	12	9	3	8	5	6	6	7	13	5
12	8	15	15	3	5	6	4	3	8	4	7	11
13	15	9	9	2	8	2	5	2	5	10	14	11
14	14	5	7	6	4	2	4	1	3	7	10	10
15	9	7	9	4	4	1	2	5	4	8	9	13
16	10	8	9	9	2	6	2	4	7	3	10	10
17	8	9	6	5	4	4	3	3	1	8	6	15
18	12	8	7	5	7	1	5	3	4	4	7	10
19	12	7	10	2	8	2	4	2	5	12	7	9
20	14	7	14	5	9	2	2	2	3	8	9	16
21	8	8	9	6	1	5	5	6	2	6	8	10
22	13	9	10	6	1	3	5	6	3	6	8	10
23	12	9	10	7	2	3	3	6	11	4	12	3
24	15	9	8	6	3	3	6	4	5	9	13	7
25	14	10	4	6	6	4	6	4	7	8	9	11
26	11	17	8	2	4	4	2	1	6	8	10	11
27	14	11	6	2	5	2	3	3	8	7	5	7
28	9	9	6	4	4	3	...	7	5	7	12	13
29	13	(3)	5	1	1	3	5	5	8	6	11	10
30	15		7	1	2	2	4	5	12	7	9	8
31	15		7		1		1	8		7		8

TABLE VIII.—Five-day Totals in the Non-Instrumental Meteorology of London, 1763 to 1896.

[Note.—As regards Mist and Fog the values refer to the 86 years, 1811-96.]

Period.	Thunderstorms.	Lightning.	Mist and Fog.	Dense Fog.	Snow.	Hail.	Gales.	Period.	Thunderstorms.	Lightning.	Mist and Fog.	Dense Fog.	Snow.	Hail.	Gales.
Jan.								July							
1 to Jan. 5	2	2	60	10	106	8	50	5 to July 9	64	10	3	1	0	2	19
6 ,, 10	1	7	61	14	89	4	41	10 ,, 14	50	12	6	0	0	2	21
11 ,, 15	1	3	53	11	91	5	54	15 ,, 19	68	19	7	1	0	6	16
16 ,, 20	0	3	61	11	79	10	56	20 ,, 24	62	9	13	0	0	3	21
21 ,, 25	3	5	60	14	71	8	62	25 ,, 29	57	7	10	2	0	3	16
26 ,, 30	2	3	47	10	73	9	62	30 to Aug. 3	61	19	9	1	0	4	10
31 to Feb. 4	1	3	39	10	84	5	48	Aug.							
Feb.								4 ,, 8	53	18	17	3	0	1	18
5 ,, 9	1	7	46	9	62	18	58	9 ,, 13	48	22	9	2	0	0	20
10 ,, 14	1	0	47	8	78	17	52	14 ,, 18	45	14	17	5	0	3	16
15 ,, 19	1	2	61	8	78	13	39	19 ,, 23	38	16	19	2	0	5	22
20 ,, 24	2	1	46	9	76	21	42	24 ,, 28	33	18	25	5	0	6	19
25 to Mar. 1	2	2	27	6	82	21	62	29 to Sep. 2	35	18	26	3	0	4	25
Mar.								Sep.							
2 ,, 6	3	0	36	7	76	19	59	3 ,, 7	34	20	36	3	0	4	13
7 ,, 11	3	3	44	5	89	30	60	8 ,, 12	23	12	50	7	0	3	28
12 ,, 16	1	2	33	1	69	27	49	13 ,, 17	20	9	64	11	0	4	20
17 ,, 21	6	1	44	5	62	31	46	18 ,, 22	17	17	57	10	0	6	17
22 ,, 26	4	3	32	3	81	30	40	23 ,, 27	15	14	66	14	2	1	37
27 ,, 31	5	3	35	8	45	31	31	28 to Oct. 2	21	15	69	21	0	4	39
April								Oct.							
1 to April 5	14	4	28	2	34	39	40	3 ,, 7	7	17	69	13	1	3	29
6 ,, 10	13	3	22	1	18	29	26	8 ,, 12	13	14	67	10	1	4	37
11 ,, 15	16	5	24	2	39	32	24	13 ,, 17	6	5	90	18	1	6	36
16 ,, 20	17	4	21	1	33	32	26	18 ,, 22	5	11	72	6	5	5	36
21 ,, 25	14	11	15	2	16	29	31	23 ,, 27	4	19	70	18	4	3	36
26 ,, 30	21	10	17	3	10	38	10	28 to Nov. 1	4	11	57	6	7	3	35
May								Nov.							
1 to May 5	32	11	9	2	8	28	21	2 ,, 6	1	10	81	16	5	6	38
6 ,, 10	28	8	6	1	5	18	21	7 ,, 11	7	5	85	22	10	6	35
11 ,, 15	25	8	7	1	3	21	24	12 ,, 16	3	1	80	20	12	3	50
16 ,, 20	29	10	14	2	2	20	30	17 ,, 21	1	5	80	24	24	3	37
21 ,, 25	32	7	14	1	1	18	13	22 ,, 26	6	9	75	23	28	7	52
26 ,, 30	33	9	11	1	1	10	16	27 to Dec. 1	5	10	66	9	24	5	43
31 to June 4	28	9	8	0	0	5	18	Dec.							
June								2 ,, 6	4	3	54	6	42	6	57
5 ,, 9	53	7	14	1	0	10	13	7 ,, 11	2	6	79	17	47	6	53
10 ,, 14	38	10	14	2	0	8	23	12 ,, 16	0	8	75	12	31	6	55
15 ,, 19	49	11	12	2	0	10	14	17 ,, 21	3	9	63	11	61	5	60
20 ,, 24	36	15	7	0	0	7	16	22 ,, 26	1	4	85	21	67	9	42
25 ,, 29	55	9	7	1	0	6	16	27 ,, 31	3	4	74	20	75	4	46
30 to July 4	47	11	5	0	0	1	22								

DISCUSSION.

The President (Mr. E. Mawley) said that this was the second paper on the subject they had heard from Mr. Mossman, the compilation of which must have entailed a large amount of work, and he was sure the thanks of the Society were due to Mr. Mossman for bringing it before them.

Dr. H. R. Mill thought the paper of special value, dealing as it did with facts and figures which a Government Department would ignore, and only an

individual enthusiast care to attack. Mr. Mossman had worked with great perseverance. He had wonderful faculties for boiling down records and constructing curves, which formed a sound foundation for comparisons. Whenever anything very unusual in the way of meteorological phenomena occurred, it was often said "that the oldest inhabitant had never experienced anything like it." Now this "oldest inhabitant" almost always had a weak memory, and he Dr. Mill, thought that Mr. Mossman's figures would furnish a much sounder and more satisfactory standard of comparison.

Mr. G. J. SIMONS endorsed all that had been said with regard to the value of the paper. With reference to the thunderstorm curve it reached, as was to expected, a very high percentage in July, but he was surprised that there were so few winter storms. The absence was not nearly so marked in the curve of lightning without thunder, perhaps because the greater length of the winter night enabled it to be more readily seen. With regard to hail, he thought that the explanation of the well-marked maximum in April was that "graupel" had been included. The maximum of thunderstorms was in July, and it was then that the maximum of true hail would be expected.

Mr. F. J. BRODIE cordially agreed with all that had been said in praise of the paper, and fully appreciated the vast amount of labour that must have been spent in its preparation. An examination of the thunderstorm curve did not, however, support the statement as to the absence of any increase in this phenomenon in the month of April. On the contrary, it showed a decided increase in April, followed by an almost complete check in May. The fogs usually experienced in September were night and morning fogs, especially when anticyclonic conditions prevailed, the days being often quite clear. He was surprised to hear that November was the foggiest month in the year. According to the investigation made some time ago by Mr. Scott, there was less fog in November than in December or January. Mr. Scott's figures were, it is true, derived from fifteen years' observations only. This might account for the difference in the results, another possible explanation being the fact that Mr. Mossman, in getting out his results, had included observations of "mist." Referring to the prevalence of gales, he was certainly not prepared to find that these were more numerous in July than in June or August. According to his own experience, July was the quietest month in the year.

Mr. G. CHATTERTON said it would be interesting to see the statistics for fog dissected into periods of twenty-five years. The increase in population and consumption of coal, must, he thought have had the effect of increasing the number of dense fogs to a large extent.

Mr. C. HARDING thought the tables of high value, and he should have liked to have seen them in greater detail. He thought Mr. Brodie should have mentioned his own paper with regard to fog, in which the maximum was given at December or January. In the remarks which had fallen with respect to the differences in the number of gales as given in the present paper and those by Mr. Scott, it should be remembered that while Mr. Mossman dealt with London only, Mr. Scott's results were for the whole of the British Isles. Again, Mr. Scott's paper only embraced a period of fourteen years, which was scarcely comparable with the long period discussed by Mr. Mossman. The comparatively quiet spell in October, mentioned in the present paper, had not held good during recent years, as the heavy gales of the Octobers, from 1880-90, will long be remembered. The five-day periods of Mr. Scott and Mr. Mossman also exhibited large differences.

Mr. F. C. BAYARD said that the large excess of gales experienced on the coast over stations inland must be responsible in a large measure for the differences between Mr. Scott's and Mr. Mossman's figures.

Mr. W. H. DINES said that he thought Mr. Scott had found that the nearer

to the middle of the winter, the greater the number of gales, October being the only exception to this, but Mr. Scott had dealt with the whole of the British Isles; and since, probably, but one gale occurred in London to twenty on the west coast, it might well happen that October should be calmer than November or February in London, but rougher when the whole country was taken into account. With reference to the curves, he was surprised that the long period taken by Mr. Mossman had not produced smoother ones. The question as to how long a period must be taken to give a smooth curve was very interesting. He believed that any one possessing sufficient mathematical skill and a knowledge of the theory of chances could give a definite answer to this question. It appeared plainly from these curves that 100 years was not anything like long enough.

Mr. R. H. Curtis thought it would be advisable to state again in this paper the localities in which the observations employed by Mr. Mossman had been made. This had been done in his previous paper, and it appeared that whilst some of them had been made in the City of London, close to London Bridge, a large number had been made several miles to the westward of Hyde Park corner, and others at Kennington in the south, and at Muswell Hill in the north,—places which are now included in Greater London, but which, for very many years after the commencement of these observations, were far removed from London, and were entirely rural in character. It was important that this fact should be borne in mind when comparisons are made between Mr. Mossman's results and London weather statistics of the present day, and especially so in dealing with observations of mist and fog. With reference to the increase of fog in September, although Mr. Ellis showed that the minimum amount of cloud at Greenwich occurred in that month, yet the discussion of ten years' sunshine statistics, published in the *Quarterly Journal*, vol. xxi. p. 216, showed that at Kew the month of greatest sunshine, relative to the highest possible amount, was not September but May. It had been stated that Mr. Mossman's figures for gale frequency differed to some extent from those given by Mr. Scott in his paper on Equinoctial Gales; but since the former dealt with London only, whilst the latter embraced the whole of the British Isles, it clearly was not possible to compare the actual number of gales in the way suggested.

Mr. R. C. Mossman, in reply, said he thought it possible that the reason of the number of thunderstorms for the winter months appearing to be so low, was that in the winter they were usually accompanied by winds of considerable force, which often rendered thunder inaudible. With regard to the question raised by Mr. Symons of the comparative infrequency of true hail during summer storms, he thought it was explained by the fact that it often fell in a half-melting condition and passed unnoticed, except by the most zealous observer. In the case of fogs he thought the months of October, November, and December were practically the same in point of frequency, but there seemed to be a very peculiar maximum about November 25th. With reference to Mr. Dines' remark as to the mathematical method of dealing with the observations, Prof. Schuster had attacked some meteorological data in this way with results which were far from satisfactory.

THE RAINFALL OF SEATHWAITE, BORROWDALE, CUMBERLAND.

By WILLIAM MARRIOTT, F.R.Met.Soc.

(Plate I.)

[Read December 16, 1897.]

THE name of Seathwaite is well known to meteorologists all over the world, and it has always been held to represent the wettest spot in the British Isles. The rainfall records from this place are consequently of great interest, and they have become very valuable, as they now extend over a period of 53 years.

Mr. Symons, in *British Rainfall* 1895, p. 15, gives the following history of the station:—

"Dr. J. Fletcher Miller, F.R.S., resided at Whitehaven, and in 1833 began to keep a meteorological register. Ten years later he became specially interested in the distribution of rainfall; in November 1843, he started a gauge in Ennerdale. It broke down, and in June of the following year he renewed it, and established six other stations; and in January of 1845 we have the first return for Seathwaite. . . .

FIG. 1.—View of Seathwaite, looking S.W.

"Most probably the reason for the starting of this record was the residence there of Mr. John Dixon, who was the agent for the Borrowdale Plumbago Mine, and in the garden of whose cottage the gauge has remained the whole time.

"Dr. Miller's mountain gauges were abandoned in 1853, he himself died in 1856, and at that time few took any interest in the rainfall of the district except Mr. Dixon, who went on with the Seathwaite record until a revival took place in 1863; and to the time of his death in 1866

rainfall owes much to the interest taken in it by Mr. Dixon. Since about 1863, there have been several observers, and small payments have been made in consideration of extra observations and of additional work."

The hamlet of Seathwaite, which consists of about five houses, is in a valley at the southern end of Borrowdale, and is at the foot of two high hills, viz Glaramara, which rises to the height of 2560 feet, on the south-south-east, and the Wad Hole Moor, which is nearly 2000 feet high, on the north-west. The Great Gable, 2949 feet, is about 2 miles to the south-west.

In December 1880 the Royal Meteorological Society equipped a climatological station at Seathwaite, the observations being made by the same person who measured the rainfall. The instruments are placed in a small garden surrounded by a low stone wall (4½ feet high). The thermometer screen is in the shade for some time every day, as may be gathered from the fact that in winter the sun shines there only for about two hours. The rain gauge is of the Snowdon pattern, 5 inches in diameter, and is 1 foot above the ground. The height above sea-level is 422 feet. A plan of the station and surroundings is given in *British Rainfall* 1895, p. 16.

FIG. 2.—View in Garden, looking N.E. (1885).

Mr. Symons has discussed the whole of the monthly and yearly records from the various gauges that have been in use at Seathwaite during the 50 years, 1845-94. I therefore propose only to deal with the records obtained from the Royal Meteorological Society's gauge, which extend over the 17 years, 1881-97.

The daily rainfall for Seathwaite has been printed regularly in the *Meteorological Record* since January 1886.

Table I. gives the monthly and annual rainfall for each year. From this it will be seen that during this period the wettest month was August

TABLE II.—Number of Days of Lightning without Thunder in London from 1763 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	...	...	1	...	5	...	5	2	4	5	2	2
2	...	...	...	...	1	2	2	3	3	5	2	...
3	...	...	...	2	2	3	...	5	4	4	3	...
4	1	1	...	...	2	3	4	5	4	3	2	1
5	1	1	...	2	1	...	2	5	7	3	1	2
6	1	1	...	...	1	...	2	3	3	2	2	...
7	1	1	...	1	2	2	2	1	2	5	2	...
8	3	3	1	1	2	2	2	4	2	3	2	3
9	1	1	...	1	...	3	2	5	4	3	...	1
10	1	...	1	...	3	...	1	5	3	3	...	...
11	2	...	1	...	2	2	...	5	...	3	1	2
12	...	...	1	1	2	3	2	3	3	2	...	2
13	1	...	1	1	2	3	5	4	2	1	...	1
14	...	...	...	1	1	2	4	2	...	1	1	1
15	...	...	...	2	1	5	5	3	2	1	...	2
16	...	1	...	2	4	3	6	4	1	1	...	2
17	1	...	...	...	3	2	3	1	4	1	2	3
18	...	1	1	1	2	...	1	4	1	1	...	2
19	1	...	...	1	1	1	4	4	2	2	1	1
20	1	1	...	...	...	4	3	3	5	4	1	1
21	...	...	...	...	2	2	2	3	5	...	1	2
22	1	...	1	2	...	4	...	3	4	4	2	2
23	...	...	...	4	1	1	2	3	4	3	...	...
24	1	...	1	4	3	4	2	4	6	4	3	...
25	3	...	1	1	1	3	1	4	...	3	2	1
26	1	1	...	4	2	2	2	4	1	7	2	1
27	1	...	...	2	...	1	1	2	3	2	1	...
28	1	...	...	1	3	1	1	4	2	...	1	2
29	...	...	1	...	2	2	2	5	2	2	4	1
30	...		1	3	2	...	3	3	1	3	2	1
31	2		1		1		6	3		4		...

TABLE III.—Number of Fogs on each Day of the Year in London from 1811 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	11	9	3	10	1	3	1	1	7	12	12	13
2	15	9	8	4	3	3	...	1	5	16	12	14
3	10	9	9	5	1	1	2	2	7	9	18	7
4	14	7	6	3	1	...	1	2	7	12	11	9
5	10	8	7	6	3	2	1	6	8	15	15	11
6	17	12	6	6	...	4	...	4	10	15	17	13
7	15	7	8	7	2	2	1	3	4	18	20	8
8	8	7	8	5	3	4	...	...	10	12	18	16
9	10	12	11	2	...	2	1	1	9	13	17	15
10	11	7	12	2	1	3	1	2	10	10	13	20
11	8	8	5	7	2	1	1	1	13	13	16	20
12	14	11	8	7	1	3	2	2	8	17	21	15
13	11	8	6	2	1	4	1	3	15	21	17	17
14	14	13	5	5	2	3	1	1	9	19	16	16
15	6	11	7	3	2	1	2	2	14	15	10	14
16	12	11	7	4	2	1	2	4	9	19	16	13
17	9	14	10	5	6	3	1	3	17	16	18	17
18	16	13	9	4	...	2	...	7	11	14	17	11
19	12	12	14	4	3	5	2	3	13	15	16	10
20	12	8	13	4	3	...	1	4	8	14	12	12
21	12	10	8	6	3	1	...	2	13	16	17	13
22	12	14	9	1	7	2	4	5	12	13	17	21
23	12	8	6	1	1	3	5	5	13	15	18	18
24	11	6	6	5	2	1	3	7	12	13	16	17
25	13	6	3	2	1	2	1	8	15	16	13	16
26	8	5	8	2	4	1	1	2	12	16	11	13
27	11	7	7	4	2	2	2	3	14	10	16	16
28	11	6	6	3	3	...	2	5	18	13	14	16
29	10	(2)	9	3	1	2	4	4	11	12	12	13
30	7		8	5	1	1	3	6	12	13	11	14
31	5		5		1		2	4		7		15

TABLE IV.—Number of Dense Fogs on each Day of the Year in London from 1811 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2	3	...	1	...	...	...	...	1	4	...	2
2	2	2	2	...	...	...	...	...	1	6	4	4
3	2	1	2	...	1	...	...	...	1	2	5	...
4	3	4	2	...	1	...	...	1	..	4	3	...
5	1	2	2	1	...	...	1	1	1	4	2	...
6	5	...	...	1	...	...	...	...	1	2	2	2
7	2	2	1	...	1	...	...	1	...	2	4	1
8	2	2	2	...	...	1	...	...	2	1	6	4
9	1	3	...	...	...	...	...	1	1	3	3	2
10	4	2	2	...	...	2	...	...	2	4	4	4
11	4	2	...	1	...	...	...	...	...	...	5	6
12	4	2	...	...	1	...	...	...	2	2	5	3
13	2	1	...	...	...	...	...	1	3	6	4	4
14	1	1	...	...	...	...	...	1	...	2	3	1
15	...	2	1	1	...	...	...	...	2	7	4	3
16	...	2	...	1	...	...	...	2	3	2	4	2
17	3	2	2	...	1	...	1	1	3	1	7	3
18	4	1	2	...	...	...	...	1	2	2	4	2
19	3	1	1	...	...	2	...	...	1	2	5	4
20	1	1	...	...	1	...	...	1	1	1	3	2
21	3	1	2	1	...	...	...	...	3	1	5	2
22	2	2	...	...	...	...	...	1	3	1	4	6
23	3	3	...	...	...	...	...	...	1	5	8	4
24	2	2	2	1	1	...	...	2	2	5	6	5
25	5	3	1	...	...	...	...	2	4	2	4	2
26	2	1	...	...	...	...	...	...	2	3	1	4
27	...	...	1	1	1	...	...	...	5	3	2	4
28	3	2	1	1	...	1	2	1	4	2	1	3
29	4	(...)	3	...	...	...	...	...	3	3	3	4
30	2		2	1	...	...	1	1	4	1	1	3
31	...		1		...		...	...		...		6

TABLE V.—Number of times Snow fell on each Day of the Year in London from 1763 to 1896.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	22	19	16	11	1	...	...	...	...	...	1	6
2	22	22	16	10	1	...	...	...	...	...	1	6
3	22	13	20	6	2	...	...	...	...	...	...	11
4	15	13	13	4	2	...	...	...	...	...	1	6
5	25	13	8	3	2	...	...	...	...	...	2	8
6	22	17	19	2	1	...	...	...	...	...	1	11
7	13	10	13	1	3	...	...	...	...	1	1	8
8	20	9	17	4	...	...	...	...	...	...	2	8
9	19	13	23	5	...	...	...	...	...	...	1	10
10	15	13	20	6	1	...	...	...	...	...	3	12
11	22	23	16	9	...	...	...	...	...	...	3	9
12	23	9	19	9	...	...	...	...	...	1	...	5
13	15	21	12	6	...	..	...	...	...	1	2	5
14	12	12	12	9	1	...	...	...	...	...	1	5
15	19	14	13	6	2	...	...	...	...	...	3	7
16	16	13	13	9	2	...	...	...	...	...	6	9
17	13	15	13	6	...	...	...	...	...	...	6	15
18	16	19	9	8	...	...	...	...	...	1	4	10
19	17	17	13	4	...	...	...	...	...	...	5	15
20	17	15	13	6	...	...	...	...	...	2	5	10
21	14	19	4	5	...	...	...	...	...	1	4	11
22	14	15	17	2	1	...	...	...	...	1	5	15
23	15	15	16	1	...	...	...	...	...	...	2	8
24	15	12	17	6	...	...	...	...	1	1	3	12
25	13	18	14	2	...	...	...	...	1	1	8	14
26	15	16	17	2	...	...	...	...	...	1	10	18
27	13	16	12	3	1	...	...	...	...	1	6	22
28	18	16	12	1	...	...	...	...	...	1	2	19
29	12	(4)	7	4	...	...	...	...	...	2	4	9
30	15		7	...	...	...	...	...	...	3	6	12
31	17		7		...		...	...		...		13

TABLE III.—Instances of Rainfall of 3 inches, Etc.—*Continued.*

Date.	Rainfall.	Temperature.						Wind at Fleetwood.	
		Same day.		Next day.		Extremes in 24 hours.			
		Dry.	Wet.	Dry.	Wet.	Max.	Min.	Direction.	Velocity.
	ins.	°	°	°	°	°	°		miles.
1885. July 7	3·89	56·8	55·2	56·0	51·2	57·9	52·6		
,, 18	3·04	57·0	56·1	59·9	53·0	60·6	54·3		
Aug. 10	3·20	56·0	54·0	55·1	53·4	59·7	52·5		
Nov. 26	3·38	43·1	41·1	43·0	41·1	49·4	41·9		
1886. Jan. 3	3·98	46·0	45·1	40·0	36·9	47·2	39·4		
Sept. 29	3·00	58·0	57·2	58·5	57·2	58·9	56·6	SW	856
1887. Feb. 22	3·16	44·0	43·1	46·0	45·1	47·3	44·0	SSW	796
1888. Oct. 26	3·55	56·2	54·7	57·9	57·2	58·6	56·2	SSW–S	565
,, 27	4·56	57·9	57·2	57·8	56·2	60·4	55·9	S	749
Nov. 23	3·55	49·4	45·1	51·9	50·2	52·9	40·4	WSW–SW	914
Dec. 2	3·53	49·7	48·2	51·4	50·4	52·6	42·4	S	684
,, 3	3·20	51·4	50·4	50·1	49·7	54·6	43·4	S–SW	701
1889. Jan. 29	3·08	47·7	46·1	43·9	43·1	47·7	38·2	NW–SW	841
Feb. 13	3·10	38·4	38·1	40·4	39·1	47·6	38·4	SSW–W	771
Dec. 19	3·84	43·2	40·9	37·7	35·3	44·9	36·6	S–NW	581
1890. June 2	3·48	51·8	48·2	50·8	49·2	56·4	47·4	W–SW	761
Sept. 30	6·78	53·3	52·2	54·8	52·2	61·3	51·4	SW–WSW	1115
1891. Aug. 24	6·12	52·8	50·7	55·3	53·5	57·6	52·8	SW–SSW	861
,, 25	4·08	55·3	53·5	53·8	50·2	59·6	49·4	SW–S	1018
,, 31	3·30	54·3	53·9	55·6	51·4	60·6	50·1	S–SW	1020
Sept. 5	4·57	53·8	51·0	48·8	47·5	55·6	46·4	WSW–SSW	874
,, 30	3·30	54·0	50·2	46·8	45·3	55·4	45·4	S–W	496
Dec. 8	3·13	43·1	41·6	44·5	40·6	46·6	39·7	W–S–W	632
1892. Sept. 1	5·36	54·6	52·9	51·8	48·9	56·6	48·4	SW–WNW	997
,, 18	5·78	53·5	49·7	55·8	53·5	57·1	52·4	S–W	809
1893. Feb. 9	3·50	44·3	41·6	45·0	42·4	46·1	39·4	SW–W	1108
,, 13	4·94	34·5	33·0	46·1	45·6	46·6	33·3	S–SSW	556
Mar. 1	4·10	35·8	35·0	43·8	43·1	46·3	34·1	SW–W	907
July 18	3·18	57·1	54·0	57·9	56·2	61·1	52·1	W–SSE–WSW	571
Oct. 15	3·69	56·8	56·2	56·6	54·9	58·3	53·9	SW	677
Dec. 24	3·71	42·8	41·8	41·3	38·1	48·6	37·3	SSE–W	900
1894. Jan. 26	4·36	35·5	32·8	45·8	44·8	47·1	34·3	W–SW	965
Feb. 6	3·64	45·8	45·1	50·2	48·9	52·1	45·4	SSW–SW	1089
Mar. 5	4·22	39·8	37·0	41·3	38·4	46·0	38·4	SW–W	1059
Oct. 24	4·11	53·3	52·2	49·5	47·8	54·3	46·7	SE–WSW	1019
Nov. 1	3·58	56·0	54·2	54·8	52·9	57·3	48·4	SSE–S	617
1895. Mar. 23	4·41	45·8	44·1	44·8	42·9	48·6	42·4	S–SW	796
Aug 26	4·44	56·0	54·2	57·7	54·5	62·1	54·4	SSE–WSW	624
Dec. 4	4·02	43·3	41·1	47·8	44·4	51·9	43·3	SW	1167
1896. Feb. 7	3·13	45·0	43·1	50·5	49·0	51·6	43·4	SSE	674
Dec. 29	4·59	38·8	35·0	48·1	46·8	48·6	38·1	SSE–SSW	660
1897. Sept. 23	3·42	52·8	50·5	56·8	55·5	59·3	50·4	SSW–SW	829
Nov. 12	8·03	50·8	49·4	52·5	50·2	56·1	50·4	SSE–S	736

With the view of ascertaining the atmospheric conditions under which the heavy rainfalls occurred at Seathwaite, I took out all the falls exceeding 1 inch for the years 1881-85 and compared them with the direction and force of the wind at Barrow-in-Furness, as given in the *Daily Weather Reports*. This work became so extensive that I had to restrict the comparison to falls of 2 inches and upwards. This examination showed clearly that the heavy rainfalls at Seathwaite occurred when the wind was between South-East and West, and the force 5 or more, on the Beaufort scale. In fact, whenever the force of the wind reached 7, or a gale, the rainfall at Seathwaite was almost sure to be 2 inches or more.

As the observations at Barrow-in-Furness were only made twice a day, viz. at 8 a.m. and at 6 p.m., and as they were not published after 1889, I considered that a stricter and better comparison would be obtained by using the records of the anemograph at Fleetwood. Mr. Scott gave me permission to utilise the tabulations of the anemograms in the Meteorological Office, as the results are not published. These records commenced in September 1886.

FIG. 3.—Looking W.N.W. across Garden and Cottage to Greyknotts (1885).

Table III. gives all the rainfalls of 3 inches and upwards during the 17 years, 1881-97. As the rainfall day extends from 9 a.m. to 9 a.m. the next day, I have given in this Table the readings of the dry and wet bulb thermometers at 9 a.m. on both days, and also the maximum and minimum temperatures during the 24 hours. The last two columns of the Table give the direction and total velocity of the wind at Fleetwood during the corresponding 24 hours, ending 9 a.m. since 1886. It will at once be seen that the general direction of the wind is South to South-West, and that the velocity is high, ranging from 496 to 1167 miles (factor 3) in the 24 hours. If these are grouped according to the rainfalls the following remarkable results are shown :—

SEATHWAITE.		FLEETWOOD.	
Rainfall.	No. of instances.	Wind Velocity.	
		(Factor 3).	(Factor 2·2).
3 inches.	21	766 miles.	561 miles.
4 ,,	12	866 ,,	636 ,,
5 ,,	2	903 ,,	662 ,,
6 ,,	2	988 ,,	724 ,,
8 ,,	1	736 ,,	539 ,,

Thus it appears that the stronger the wind, the heavier is the rainfall at Seathwaite.

In order to understand this, we must examine the topography of the surrounding district (Plate I.)

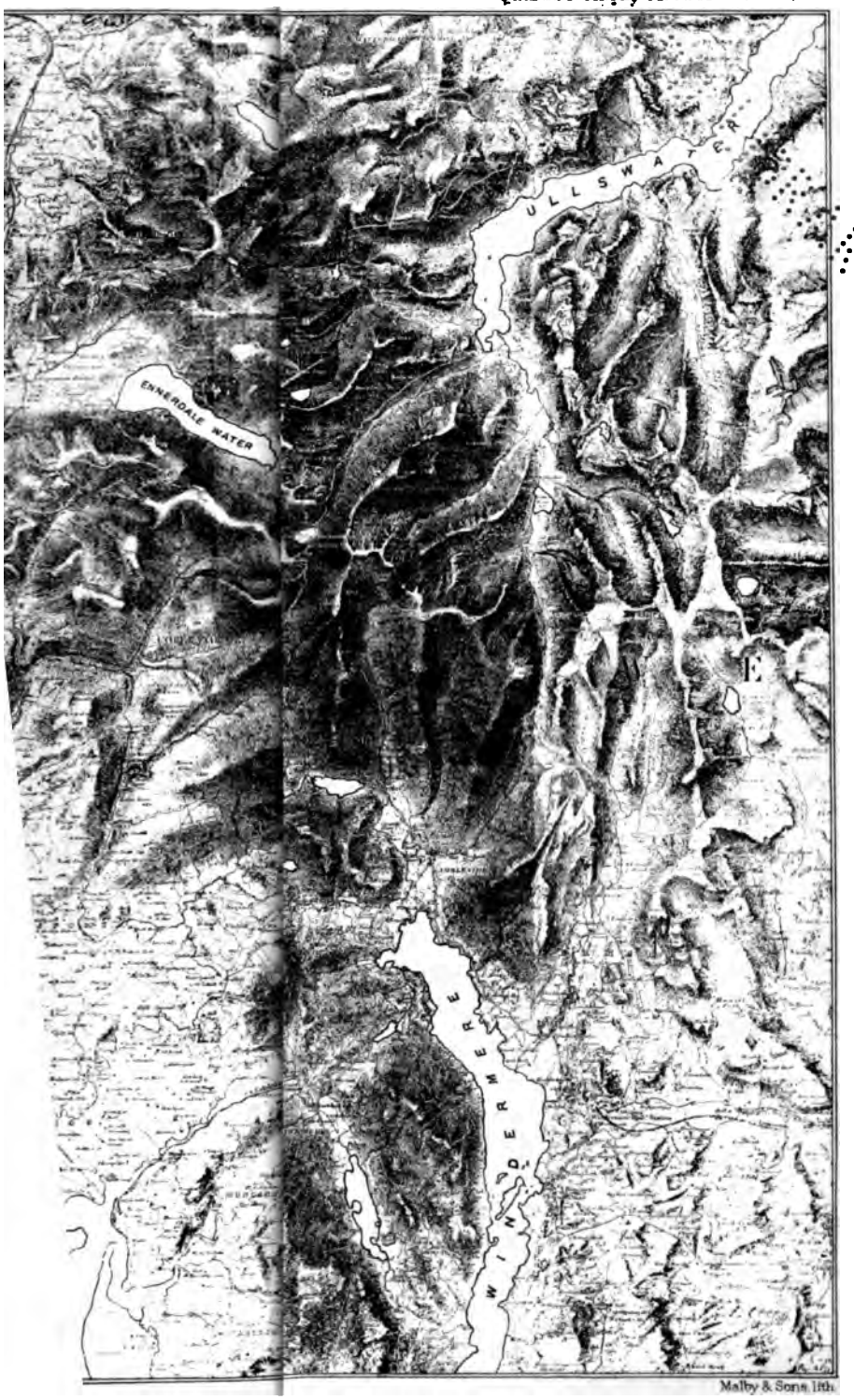
Seathwaite is in a valley to the north of the highest mountain in England, Scafell Pike, 3210 feet, which is only about 3 miles distant; to the east of this mountain rises Bow Fell to a height of 2960 feet. On the west of Scafell lies the deep valley of Wasdale, on the north of which is Kirk Fell, 2631 feet, and Great Gable, 2949 feet. Communication between Wasdale and Borrowdale is by the Styhead Pass, which rises to about 1500 feet. To the east of Bow Fell there is the valley of Langdale.

Now it will be readily seen that when the wind is between the South-East and West, it will be concentrated in these valleys, and must rush up them with considerable force. In addition to this, the air current will have swept over the Irish Sea and Morecambe Bay without any obstruction until it reaches Furness and these hilly districts. Consequently, the air current will not only have to get over these passes, but will be forced up to a greater height. It is this forcing up of the air current, and consequent reduction of temperature, which is the cause of the heavy rainfall on the leeside of the Scafell range.

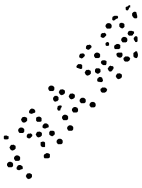
The Southerly winds occur in the south-east quadrant of a depression or cyclone, where the air is warm and humid. When the air current reaches 3000 feet it will probably be reduced in temperature about 10°. But the air current, when passing over these mountains and up the steep passes, must be driven up to a much greater elevation. Suppose it should be to 4000 feet. The air would be reduced in temperature about 13°. Now the air at 50° can contain 4·10 grains of vapour in a cubic foot, but at 37° it can only contain 2·57 grains. Consequently, it must part with 1·53 grains, which will be deposited in the form of rain. With such a process going on continuously for 12 or 24 hours, the heavy rainfall at Seathwaite is fully accounted for.

It will be seen from the temperatures given in Table III. that there is always a difference between the dry and wet bulb readings, frequently of several degrees; showing that, notwithstanding the great precipitation, the air is very dry. This, at first sight, may perhaps seem strange. But the air in passing over the mountains has parted with a very considerable amount of its moisture, and, as it descends from 3000 or 4000 feet to 420 feet, it comes down much drier and warmer. It is no doubt due to this cause that Seathwaite enjoys a milder and more equable climate than many other parts of the country.

It has been generally accepted that rainfall increases with elevation up to certain limits, beyond which it decreases. Dr. Miller started a number of mountain gauges with the view of finding out what this limit was. He came to the conclusion that the limit was about 2000 feet. In *British Rainfall* for 1896, Mr. Symons has collected together the results from Dr. Miller's, and also from other gauges in this district, the positions of which are marked on a contoured map. He has grouped the results according to altitude, but they do not agree together. Mr. Symons, however, says, "that the influence of position with respect to hills and valleys is far greater than that of altitude." This has been fully borne out in what I have already stated. If we carefully examine the contour map we shall find that the Stye is the spot where the greatest rainfall would be most likely to occur.



Malby & Sons, lith.



DISCUSSION.

The President (Mr. E. MAWLEY) said that this paper had been prepared by Mr. Marriott at the request of the Council, and had proved extremely interesting. It was remarkable that the rainfall in the Lake district had been so heavy during the past autumn, which was in marked contrast to the dry weather experienced in other parts of England.

Mr. G. J. SYMONS congratulated Mr. Marriott on the interesting results he had obtained, and thought that the conclusions obtained from the inquiry were very satisfactory. He (Mr. Symons) had a recollection of once giving a lecture on the subject of "Rainfall," in which he touched on the Lake district, specially remarking that the spring months were the driest period of that rainy district, and therefore the best time for taking a holiday there. The advice was taken by a gentleman with disastrous results, as the following spring proved to be of an excessively wet character, with the consequence that his (Mr. Symons) reputation on the subject was grievously shattered. The maximum fall for the whole period, viz. 8·03 ins. on November 12, 1897, seemed to have fallen expressly for inclusion in the paper. It had never been equalled at Seathwaite during fifty years' observations. This extraordinary fall was not so strictly local as might be imagined. It was limited to a small portion of the county of Cumberland, but not so limited as heavy thunderstorm rains which often only covered a few square miles. On the same day 6 ins. to 7 ins. was registered at and near Ambleside, 5 ins. to 6 ins. at Derwentwater, and what was more remarkable, taken relatively to the average, 4 ins. in the comparatively dry district round Cockermouth. With reference to the gauges situated on the Stye Head, which Mr. Marriott had difficulty in finding, it was his intention that they should be difficult to discover, as they were often tampered with by tourists. Indeed, so well are they hidden that he himself once wandered round the Stye Head Tarn for two hours looking in vain for the gauge, although he had in his possession a 6-inch Ordnance Survey Map on which the position of the gauge was plainly indicated. The gauge on the Stye, shown by Mr. Marriott on the screen, was the most southerly of the four gauges situated there, and in the picture looked close to a precipice, which in reality was much farther away. The remaining three were on a level plateau ; the largest quantity of rainfall being registered by the gauge farthest from the rock.

Mr. R. INWARDS remarked that from the photograph shown on the screen the Seathwaite gauges seemed to be too near the adjacent walls. From the contour map of the district it seemed that nearly all the valleys converged towards the region under discussion, though of course it was probable that the main influence was exercised by the Wasdale gorge. Lines drawn through the longest diameters of Windermere, Coniston, Derwentwater, Wastwater, Ullswater, and Ennerdale, would all come to a focus somewhere in this region, so that it formed a centre of condensation and of upward flow of air for winds blowing from almost all points of the compass.

Dr. H. R. MILL confirmed Mr. Inwards' remark that the valleys on the eastern side of Seathwaite converged in a similar manner to those on the western side, and he should have expected that heavy rainfall would have been experienced with winds from a North-Easterly direction. In all the works on physical geography he had read it was stated that the heaviest rainfall occurred on the windward side of mountains, but perhaps this rule was meant to apply to mountains of the altitude of the Andes, the Rocky Mountains, etc. ; it was obvious that it did not hold good in the case of the mountains in the Lake district, which were in reality only hills. He should like to ask Mr. Symons if there were any gauges situated in Wasdale, Ennerdale, or Langdale. If so,

he thought the results would be of great value taken in conjunction with the subject of the present paper.

Mr. W. MARRIOTT, in reply, said that during the first five years there were only two cases of rainfall exceeding an inch with a North-Easterly wind. This was the period during which the wind records of Barrow-in-Furness were utilised; but from a closer examination of the daily weather chart it appeared that the direction on those dates was really South-East. The probability was that Easterly winds would be dry by reason of their passage over the continent, and supposing them to be vapour-laden in some degree, it would be deposited near the east coast. Neither were North-Westerly winds so heavily charged with moisture as those from a Southerly direction. He considered the heavy rainfall entirely due to the reduction in temperature of the vapour-laden air currents consequent on their projection to a great altitude. The daily records for Seathwaite had long been published in the *Meteorological Record*, and they had always been a source of interest. With reference to Mr. Inwards' remarks concerning the exposure of the Seathwaite gauges, photographs were sometimes deceptive, but he (Mr. Marriott) thought them well exposed, the angles made with surrounding objects being less than those made with the hills themselves. The three gauges in the garden registered much the same amount, and agreed very well with the gauge situated in a field near by, though often in this district a short distance made a great difference in rainfall. A plan of the station showing the position of the gauges appeared in *British Rainfall* for 1895.

Mr. G. J. SYMONS, in reply to Dr. Mill, said that there had been gauges in Wasdale and Ennerdale, and three or four in Langdale, all of them registering large amounts, though not so large as Seathwaite, their average being about 110 ins. That in Wasdale is only read monthly, but there are now daily records in Langdale, several in Borrowdale, one above Buttermere, others near Elterwater, Grasmere, etc., so that if any one had the leisure to do it the influence of the direction of the wind on the amount recorded could easily be studied.

PROCEEDINGS AT THE MEETINGS.

November 17, 1897.

Ordinary Meeting.

EDWARD MAWLEY, F.R.H.S., President, in the Chair.

The following letter from the HOME SECRETARY was read:—

"WHITEHALL, *8th July* 1897.

"SIR,

"I have had the honour to lay before the Queen the loyal and dutiful Address of the President, Council, and Fellows of the Royal Meteorological Society, on the occasion of Her Majesty attaining the Sixtieth year of Her Reign, and I have to inform you that Her Majesty was pleased to receive the same very graciously.

"I have the honour to be,

"Your obedient servant,

"M. W. RIDLEY.

"Francis Campbell Bayard, Esq., LL.M.
"Royal Meteorological Society."

CHARLES ABURROW, Assoc.M.Inst.C.E., Johannesburg, South Africa;
WILLIAM BERRIDGE, 9 Forest Road, Loughborough;
RONALD STANLEY CLARKE, Homelea, Cross-in-Hand, Sussex;
LAWRENCE GIBBS, Assoc.M.Inst.C.E., P.W.D., Hong-Kong;
SHOLTO HENRY HARE, F.R.H.S., 7 Titfield Place, Clifton, Bristol;
HENRY GEORGE HOLLINGWORTH, F.R.G.S., Llanbedr, R.S.O., Merionethshire;
MAJOR HENRY KING, Isfield Place, Uckfield; and
ARTHUR NEWSHOLME, M.D., Town Hall, Brighton,
were balloted for and duly elected Fellows of the Society.

The following communication was read:—

"SUNSHINE RECORDERS AND THEIR INDICATIONS." By RICHARD H. CURTIS, F.R.Met.Soc. (p. 1).

December 15, 1897.

Ordinary Meeting.

EDWARD MAWLEY, F.R.H.S., President, in the Chair.

LEONARD ADDENBROOKE, 13 Bourne Street, Dudley;
JAMES DIGGLE, Assoc.M.Inst.C.E., F.G.S., The Hollies, Heywood;
ERNEST ROMNEY MATTHEWS, Borough Engineer's Department, Hastings;
THOMAS THEOPHILUS SECUNDUS METCALFE, J.P., Roche Court, Salisbury; and
WILLIAM ORMEROD, J.P., Scaitcliffe Hall, Todmorden,
were balloted for and duly elected Fellows of the Society.

Mr. F. GASTER and Mr. M. JACKSON were appointed Auditors of the Society's Accounts.

The following communications were read:—

"DAILY VALUES OF NON-INSTRUMENTAL METEOROLOGICAL PHENOMENA IN LONDON, 1763-1896." By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc. (p. 31).

"THE RAINFALL OF SEATHWAITE, BORROWDALE, CUMBERLAND." By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 42).

CORRESPONDENCE AND NOTES.

Note on Maximum Thermometers.—I wish to call attention to a "Note on Maximum Thermometers," by Mr. Thomas Walker Fowler, in the *Quarterly Journal*, October 1897, pp. 305-6, which is apparently somewhat in error. The case considered is a special instance of the correction for "emergent column." If the constriction come at t_o, and if t be the reading taken when the air and thermometer have fallen to temperature t', the true correction x is given by

$$x = (\mathrm{E} - e)(t - t_o)(t - t');$$

where E = coefficient of expansion of mercury,
" e = " " glass.

The proof is simple, viz.—

$$(t - t_o)\{1 + \mathrm{E}\,(t - t')\} = (t + x - t_o)\{1 + e\,(t - t')\}.$$

Hence, as x is small and E and e very small, we have as first approximation—

$$x = (\mathrm{E} - e)(t - t_o)(t - t').$$

At ordinary air temperatures we may put $E = \cdot 000101$, and for ordinary glass $e = \cdot 000014$ is at least a good approximation. These figures refer to the Fahrenheit scale.

Thus we may put— $x = \cdot 000087 (t - t_0)(t - t')$.

Taking Mr. Fowler's extreme case, $t = 110$, $t_0 = -14$, $t' = 40$, we have, to the nearest $0^\circ \cdot 05$,

$$x = \cdot 000087 \times 124 \times 70 = 0^\circ \cdot 75.$$

Mr. Fowler has $0^\circ \cdot 9$ instead; and all his other numerical results appear similarly exaggerated when they are large enough to show an error of 16 per cent. The explanation, I should think likely, is the omission on Mr. Fowler's part to notice that the glass changes volume as well as the mercury. For if we neglect e, and so take

$$x = E(t - t_0)(t - t') = \cdot 000101 (t - t_0)(t - t'),$$

we can reproduce Mr. Fowler's figures.

A perhaps more elegant way in which to present the correction is—

$$x = \frac{(t - t_0)(t - t')}{N},$$

where N = the number of degree volumes in the bulb of the thermometer up to the zero (32° F.). For English glass, using the Fahrenheit scale,

$$N = 11500 \text{ roughly } \left(\text{of course } N = \frac{1}{\cdot 000087}\right).$$

The German *Reichsanstalt* give the correction in a form equivalent to this last on its certificates to high range thermometers. The usual conditions, when the correction is required, are the existence of a column of mercury in the stem of a thermometer emergent from a hot liquid, whose temperature it is desired to measure. Under these circumstances the correction is not unfrequently very considerable when high temperatures are being measured.

The ordinary Kew certificate, as Mr. Fowler supposes, assumes the whole thermometer at one temperature, this being what is aimed at when it is tested.—CHARLES CHREE, Sc.D., F.R.S., November 10, 1897.

[Since writing the above I have found that Leyst has treated the problem fully in the *Repertorium für Meteorologie*, vol. xiv. 1891. In calculating a numerical table he puts $E - e = 0^\circ \cdot 000161$ C., which is equivalent to $0^\circ \cdot 000089$ F.—C. C., February 14, 1898.]

The Climatology of the Globe.—Our Honorary Member, Hofrath Hann, has conferred a lasting benefit on meteorologists by the new edition of his *Handbuch der Klimatologie*. The first edition came out in 1883, and was in one thick volume. The second edition, which has just appeared, has been extended so as to fill three volumes, containing in all 1364 pages. To our knowledge, this revision of his work has occupied all the spare time of its author for several years past; and it is perfectly astounding to see from what widely varying sources of information what a mass of matter has been got together. Dr. Hann quotes freely and at considerable length from the published works of travellers and others who have had experience of foreign climates; and most of the languages of Europe have been laid under contribution, all extracts being translated into German.

Vol. I. deals with general principles, such as solar climate, oceanic climate, mountain climate, and concludes with a notice of the work of Brückner, Croll, and others, in the search for evidences of cyclical changes of climate.

Vol. II. deals with the Tropical Regions. For these the information is

mostly sporadic, for there are but few stations near the equator where meteorological observations have been kept up for more than a few years, and for many parts of the torrid zone no information is obtainable.

Vol. III. deals with the Temperate and Frigid Zone; and here, of course, there is comparative abundance of material to work upon. The reader must not, however, look for detailed data for every station. Dr. Hann takes typical districts, and gives tables of temperature and precipitation. Of the former he usually gives the figures only for the extreme months, and sometimes for the four months January, April, July, and October. In addition, we find tables for annual extremes and for the monthly variability. For the rain, monthly values are printed, but only for comparatively few stations, owing to want of space.

The entire work bears the stamp of a master hand, and the general summaries for the several districts are worked out to the minutest particulars. The sources of information are always conscientiously specified, and the extracts from published works are most interesting reading, and occupy a large space in the volumes.

The Highest Barometer-Reading.—At Irkutsk, on December 20, 1896, the barometer, at 2.30 a.m., stood at 805·6 mm. (31·717 ins.), reduced to sea-level, and to gravity for 45° lat. The temperature at the time was – 32° C. (– 25°·6 F.), and was not remarkably low for the season and place. A. V. Vosnesensky discusses the reduction of the reading in a recent number of the *Izvestiya* of the East Siberian Branch of the Imperial Russian Geographical Society, and explains that the official maximum pressure of 808·4 mm. (31·827 ins.) published for December 20, 1896, by the Central Observatory in St. Petersburg, was the result of continuing to use the erroneous height of 491 m. (1611 ft.) as the altitude of Irkutsk, instead of the more accurate determination of 470 m. (1542 ft.).

Surface Currents of the North Sea.—In connection with certain fishery problems, experiments were begun a few years ago by the Fishery Board for Scotland, with the view of ascertaining the course and speed of the surface currents off the east coast of Scotland. These experiments have now been completed, and Dr. T. W. Fulton has given a summarised account of the results in the *Scottish Geographical Magazine*, December 1897.

The experiments were begun in September 1894, and were continued until the spring of 1897. During that time 3553 floats were set adrift in the North Sea, or to the west of the Orkney and Shetlands Isles, and 502 of these had been returned by March 1897. The floats recovered were found on the eastern side of Britain, from the Orkneys and Shetlands in the north, to Norfolk in the south, and on the coasts of Holland, Germany, Denmark, Sweden and Norway, where some were picked up north of the Lofoden Islands within the Arctic circle; they were thus scattered along nearly 2000 miles of coast.

The author's conclusions are as follows:—

1. There is at all seasons a fairly constant slow circulation of the surface water in the North Sea, Atlantic water entering round the north of Scotland, and between the Orkneys and Shetlands, and passing southwards along the east coasts of Scotland and England, as far as the neighbourhood of the Wash, then in an east-north-easterly direction towards the coast of Denmark, and then northerly along the Danish coast. The surface water may or may not enter Skager Rack, and penetrate to the west coast of Sweden and the south coast of Norway. The main body passes up the west coast of Norway, and joins the Atlantic stream. The limit between the north-going eastern stream and the south-going western stream varies greatly, probably according to the prevailing winds; as a rule, the extent of the former is greater.

2. The movement of the surface water in confined areas, like the western

part of the Moray Firth and the Firth of Forth, is irregular, and depends upon variations in the winds and tides.

3. While the general circulation of the surface water in the North Sea is as above described, the current may be deflected by the wind, or even under exceptional meteorological conditions reversed.

4. The speed of the movement is usually about 2 or 3 geographical miles a day, but may be much accelerated or retarded by the action of the wind.

5. The principal cause of the circulation is probably the influence of the prevailing winds, driving the water towards the eastern side and tending to heap it up there.

RECENT PUBLICATIONS.

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. October—December. 1897. 4to.

The principal articles are:—Einige Resultate der fünfjährigen Beobachtungen auf dem Eiffelthurme: von A. Woeikof (7 pp.). This is a discussion of some of the results given in M. Angot's paper in the *Annales du Bureau Central Météorologique de France* for 1894. The chief point dwelt upon is the comparison of wind force with the daily march of temperature. Three stations are taken at different levels in the tower, and Parc St. Maur, as base for temperature, the Bureau Météorologique, at the foot of the tower, for wind. It is found that the epochs of maximum and minimum wind force are not the same at all the levels. A very interesting result of the temperature observations is that there is no evidence discoverable of the existence of the conditions required for the generation of ascending currents, such as are generally assumed by writers on the movements of the atmosphere; so that the theories of Dr. Sprüng are not confirmed.—Die ganze Temperaturschwankung im arktischen und äquatorialen Seeklima: von A. Woeikof (3 pp.). This is an account of all the oscillations of temperature, periodical and non-periodical, for some months at Batavia and Sagastyr, at the mouth of the Lena. In January there are nearly as many days with non-periodical oscillations at Batavia as in March and July at Sagastyr. But in July at Batavia these are much fewer, as that is the middle of the North-West monsoon.—Die ausserordentlichen Niederschläge in Oesterreich in der Regenperiode vom 26 bis 31 Juli 1897: von Dr. W. Trabert (10 pp.). This is an account of the rainfall which caused such frightful inundations in Austria at Lammas last. This is a complement to Dr. Hellmann's paper in the August number of the *Zeitschrift*.—Die Luftströmungen an der Erdoberfläche zu Upsala, 1891-95: von Dr. J. Westman (13 pp.). This is a discussion of the results obtained from the Upsala anemometer at Upsala. This instrument is placed at the top of the observatory; and Dr. Westman has sought to eliminate the effect of this situation on its indications by erecting a Rechnagel's anemometer on another building at a distance of 308 metres (984 feet). The relation of the wind's direction and velocity to the distribution of temperature and pressure over North-West Europe is discussed at some length.—Das Höhenklima des Staates Minas Geraes, Brasilien: von Prof. F. M. Draenert (10 pp.). Observations from Brazil are "like angels' visits, few and far between." Among the most interesting facts are that the late Director of the Geological Commission of the district, Senor Lacerda, distinguished two kinds of fog or mist. The first, *neblinas*, appear only in the morning, and are due to nocturnal radiation. The other, *nevoeiros*, are due to the condensation of the vapour of wind coming from the sea and moving over the hill ranges,

In addition, there are dry fogs due to burning the moors. These are so persistent in August that the sun looks like a red ball. This frequency of mist and fog has a great effect in protecting crops against frost.—Ueber den Einfluss der Drehungsbewegungen der Cyklonen auf die radialen und axialen Stromüngen: von W. Wien (8 pp.).—Theoretische und experimentelle Untersuchungen über das Verhalten von Thermometern, insbesondere solchen, die schnell wechselnden Temperaturen ausgesetzt sind: von H. Hergesell (14 pp.). The author is chairman of the Balloon Committee of the Paris International Meteorological Conference, and this paper is a mathematical investigation of the amount of dependence which may be placed on the readings of thermometers during balloon ascents, and the corrections which these demand.—Ueber die Einwirkung der vertikalen Komponente der ablenkenden Kraft der Erdrotation auf die Luftbewegung: von Dr. N. Ekholm (16 pp.). This is an answer to various criticisms of the author's views which were published in the *Zeitschrift* in 1894.

Rainfall Tables of the British Islands. 1866–1890. Published by the Authority of the Meteorological Council. 8vo. 283 pp. 1897.

The Rainfall Tables in this volume have been prepared in connection with those published by the Meteorological Council in 1883. The information has been supplied chiefly by Mr. G. J. Symons, by whom the earlier tables were compiled, and by Dr. Buchan, the remainder having been obtained from the reports furnished directly to the Meteorological Office. The stations represented are in all 492, viz.—in England and Wales, 287; Scotland, 151; and Ireland, 54. They have been selected from those for which materials were available, so as to show as nearly as may be the general distribution of rain over the United Kingdom, and to extend, as far as practicable, to the year 1890 the earlier records, referred to above, published in 1883. The stations thus selected cover the British Islands much more uniformly than those in the earlier publication, and have been arranged geographically, so as to offer increased facilities for reference. The registers have been divided into three parts, as follows:—Part I. gives the monthly and annual rainfall at stations in the British Islands for every year from 1881-90; for the Lustra, 1881-85, and 1886-90; and for the longest period, in complete Lustra, for which the returns for the selected stations have been published by the Meteorological Office. Part II. contains the monthly and annual rainfall at stations included in Part I. for years before 1881, but not published in 1883, with means for the several Lustra. Part III. contains an abstract of mean monthly and annual rainfall for the 10 years 1881-90, at the stations included in Part I., arranged according to counties, together with references to the tables which supply the several values. The work is illustrated by three maps, showing the main watersheds and the catchment basins of the principal rivers. The mean annual rainfall for the 10 years 1881-90 is given for almost every station, and the general distribution of rain is very well shown.

Symons's Monthly Meteorological Magazine. October—December 1897. 8vo.

The principal articles are:—Weather maps and early synchronous meteorological observations (3 pp.). In this article is reproduced a letter from Mr. J. Glaisher, F.R.S., to Prof. Henry, the Secretary of the Smithsonian Institution, dated July 8, 1850, in which the former describes the method which he had adopted for obtaining synchronous observations in the British Isles.—Sunless days and the day-distribution of sunshine in summer (2 pp.).—The rainfall of October 1897 (7 pp.). The rainfall during this month was remarkably low, especially in the south-east of England. At some stations in Sussex the total

amount was less than a tenth of an inch.—Austrian Hydrography (3 pp.).—A wet day in a wet district: by S. A. Marshall (2 pp.). On November 12, 1897, exceptionally heavy rain fell over the whole of the Lake district, the heaviest amount being 8·03 ins. at Seathwaite.

Transactions of the Royal Society of Edinburgh. Vol. XXXIX. Part I. (No. 6). 4to. 1897.

Contains:—The Meteorology of Edinburgh: by R. C. Mossman. Part II. (145 pp. and 4 plates). In Part I. the author discussed the mean values of the climatic elements for each day in the year; in the present paper he attempts to form the results deduced from an examination and reduction of the various meteorological registers kept in Edinburgh from 1731 to 1736 and from 1764 to 1896, with special reference to secular and weather changes. Detailed tables of monthly results are given for each element throughout the whole period. The author says that an examination of the facts apparent from a comparison of the reduced values for the five years 1731-36, with observations taken during recent years, shows conclusively that no appreciable alteration has taken place in the climate of the east of Scotland during at least the last 165 years. The seasonal distribution of pressure, temperature, wind and rain, is the same now as at the beginning of the eighteenth century, and so far as we can ascertain there has been no change in the annual means of the more prominent elements of climate, while the prevalent weather of special months does not appear to have altered in the slightest. These conclusions are entirely in accordance with what we should expect. As is well known, the climate of a place is largely determined by the prevailing winds; these in turn are simply the result of the distribution of the weight of the earth's atmosphere over the globe. The latter is determined by the position and extent of the land and water surfaces, and as these have not materially altered within the last 200 years, it may fairly be assumed that the circulation of the air and the climatic results springing therefrom are practically unchanged. Local influences, more especially drainage and deforesting, produce slight changes in climate; but so far as Edinburgh is concerned no alteration appears to have taken place during the last century and a half.

HON. RALPH ABERCROMBY.

BORN 1842. DIED 1897.

Frontispiece, Quart. Journ. Roy. Met. Soc. vol. xxiv.

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WEATHER INFLUENCES ON FARM AND GARDEN CROPS.

BY EDWARD MAWLEY, F.R.H.S., PRESIDENT.

An Address delivered to the Royal Meteorological Society, January 19, 1898.

(Plate II.)

THERE are few sciences so intimately connected with each other as Meteorology, Agriculture, and Horticulture. Indeed so dependent is plant life upon atmospheric conditions, that it has been found at the Experimental Farm at Rothamsted that the difference between good and bad seasons is, that double the produce can be grown in a good season to what can be raised in a bad one; even when all the necessary ingredients of plant food have been supplied to the soil. To all engaged in either agricultural or horticultural pursuits, this fact is so fully realised, that the probable effect upon the crops they grow, of prevailing or coming weather, is seldom absent from their minds. The connection is so intimate that, given detailed weather records for any year, it would be almost possible in many cases to trace the effect of the seasons upon different kinds of produce throughout the whole twelvemonth, and even to make an approximate estimate as to the ultimate yield of each. Turning to Mr. Inwards' *Weather Lore*, we at once come upon such proverbs as these: "The weather rules the field"; "'Tis not the husbandman but the weather that makes the corn grow"; "The harvest depends more upon the year than on the field"; to say nothing of hundreds of other sayings in which the weather is mentioned only in connection with agriculture. In one of the Rothamsted reports the question of the close connection between meteorology and agriculture is thus referred to: "As only about 5 per cent of the total wheat crop (the nitrogen and ash constituents) is derived from the soil itself, the remainder coming directly or indirectly from the atmosphere, and as the amount of matter accumulated from either source depends mainly on the quantity and the relations to one another of heat and moisture, we

cannot be surprised that the character of the seasons exercises such a preponderating influence on the growth of our crops."

Climate of the British Isles.

It has been said that "Climate beats Culture." This being to a great extent true, it becomes necessary to consider, before treating of the effects of different types of British weather upon British crops, the

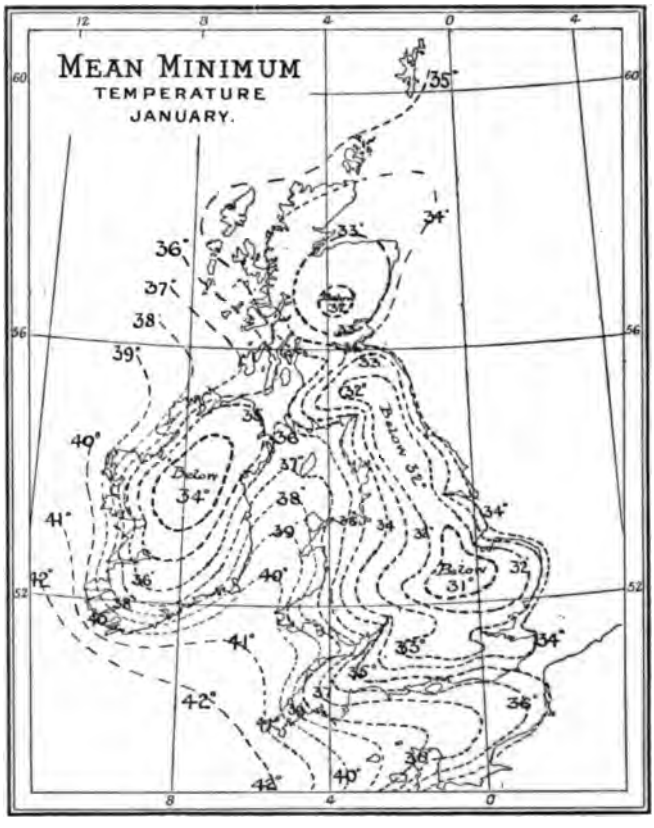


FIG. 1.

general character of our own climate. We have only to look at the isothermal chart of the northern hemisphere (Plate II.) in order to see that the general features of our climate do not depend so much on latitude as upon the unique position of these islands, situated as they are between a wide ocean on one side, and the largest continent in the world on the other. Were they dependent for temperature upon latitude alone, they would probably be as cold and infertile as Labrador. It is rather our situation in respect to the warm waters of the Atlantic, and the abundant moisture brought by the prevailing winds which blow across it, which provides us with such a mild and equable climate, as compared with other places no farther north than ourselves The

changes in weather are remarkably frequent, but owing to our moist atmosphere and cloudy skies, and the causes above mentioned, there is a marked absence of extremes of any kind. This freedom from extremes allows of a great variety of plants being grown with success, and no doubt accounts for the fact that probably a larger number of indigenous species are to be found in Great Britain than in any other country in the world of an equal extent.

Even within the limited area of the British Isles there are varieties

FIG. 2.

of climate and soil sufficiently marked to considerably influence our selection of crops and methods of culture. Take almost any ordinary farmer from a northern to a southern county, or from the south-west of England to the eastern counties, and he will for some years be at a loss how to adapt his previous experiences to his new surroundings. The maps of mean minimum temperature in January and mean maximum temperature in July, which appeared recently in Messrs. Scott and Gaster's paper[1] on the temperatures of the British Isles and which are reprinted here (Figs. 1 and 2), will show how great are the differences in temperature, at these the coldest and warmest periods of the

[1] *Quarterly Journal*, vol. xxiii. p. 275.

year, in various parts of the country. To take extreme instances. On an average January night the coast station on the extreme south-west of Cornwall will be seen to be 10° warmer than that situated in the coldest part of the midlands; whereas during the hottest part of a July day, the warmest localities in the midlands and eastern counties are at this season 10° warmer than many places in the north of Scotland. In the paper to which I refer, a correction has been applied for the height of the stations above sea-level, otherwise the lines of equal temperature would come out with much less regular curves and would show in the hilly districts marked differences within comparatively short distances.

The distribution of rain over the British Isles is so irregular, that it is not easy in a few words to describe it. There are, however, certain main features which, on looking at a rainfall map, are at once observable. For instance, it will readily be seen by the deeper shading that the average rainfall is heavier in Ireland than in England, and heavier still in Scotland. Then again, there is a more or less gradual decrease from west to east, the heaviest falls of all occurring, as a rule, where the hills are highest on the western side, while the driest localities are situated at low levels in the eastern counties.

The questions of sunshine and wind will be dealt with a little later on under their respective headings. There is, however, one characteristic feature of our climate which I have only space to mention here, and that is the large amount of moisture present, as a rule, in the air. This humid condition of the atmosphere is, of course, due to our insular position, our cloudy skies and frequent rainfall. Its effect on plant life generally is very great, and on the whole beneficial, and accounts for the remarkable verdure of a British landscape as compared with that of most other countries.

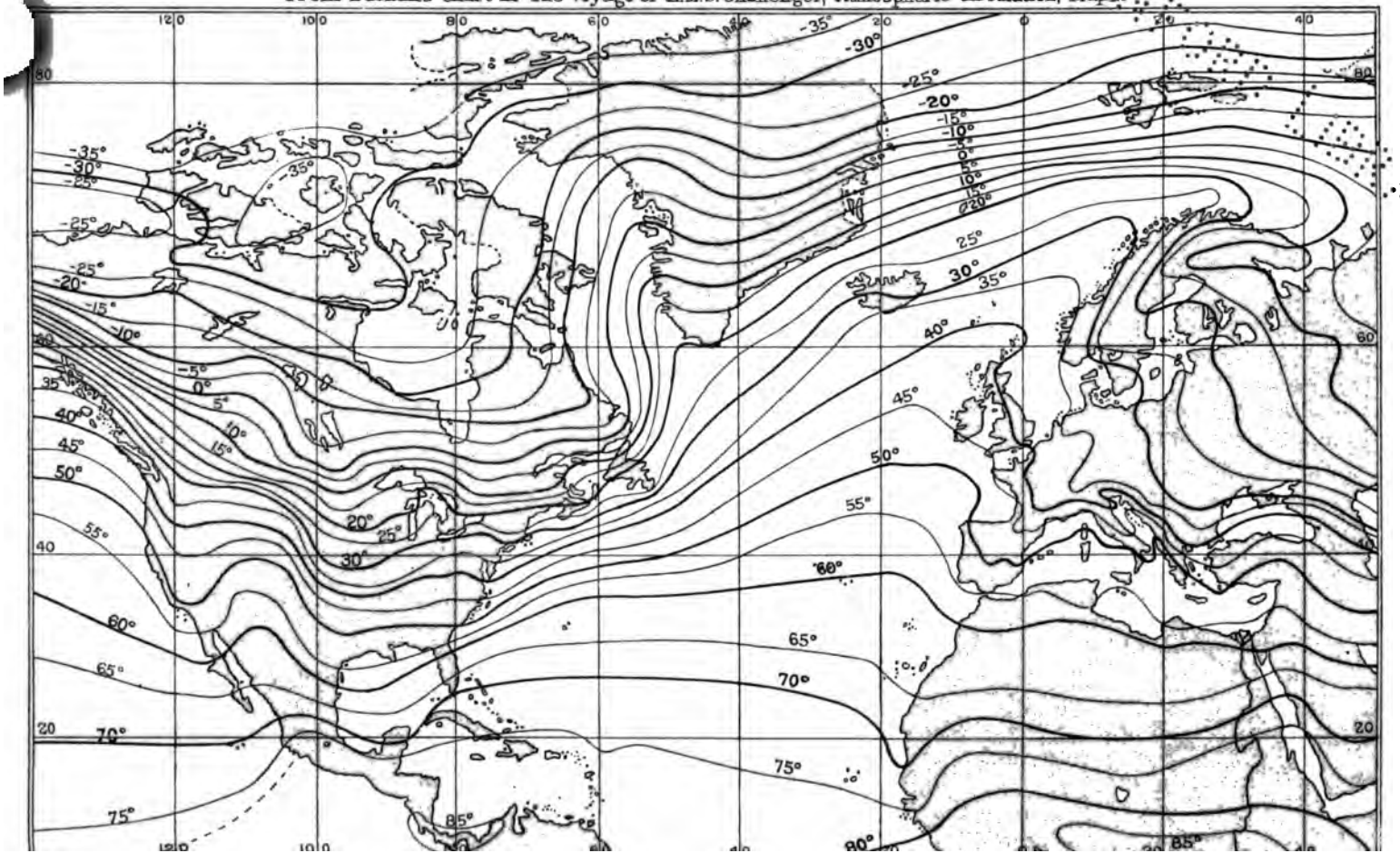
No doubt the reason why the question of the influences of weather changes upon cultivated plants has been so seldom dealt with, has arisen from the difficulty of separating the individual effects of heat, light, and moisture upon the various crops from their combined effects upon them. Besides which, most farm and garden produce vary a good deal in the time of year when they are in most active growth, the length of time they remain on the land, and the range and character of their roots. Nevertheless, it is a question of considerable importance and deserving of further investigation; seeing how dependent all cultivated plants are upon atmospheric conditions, and how all weather changes of any importance, be they favourable or unfavourable, leave their mark for a shorter or longer period on each crop.

Having given a slight sketch of the chief characteristics of the climate of the British Isles as a whole, we may now proceed to consider separately some of the effects produced on vegetation in this country by varying temperatures, by scanty and heavy rains, by sunshine and by wind; and afterwards treat of the leading farm and garden crops and their special requirements with regard to atmospheric conditions.

UNOFFICIAL DOCUMENT

ISOTHERMAL LINES SHOWING THE MEAN TEMPERATURE FOR JANUARY.

From Buchan's Chart in "The Voyage of H.M.S. Challenger," Atmospheric Circulation, Map I.



Temperature.

Of all the influences brought to bear on vegetable life by the atmosphere, that of temperature is the most powerful and far-reaching. Not only are plants affected by changes of temperature above ground, but its influence upon their roots is in most cases even more clearly to be traced. The fact is, each kind of plant and each function of its growth has its own particular requirements, as regards day and night temperatures, during its growing period; so that if these temperatures be exceeded or fallen short of, it does not thrive as well—too great warmth over-stimulating its growth, and too little checking it. Of course the wider the departure from these special temperatures, the more will its growth be injuriously affected. Then again, a certain degree of warmth must be maintained for a sufficient length of time to allow of any plant coming to maturity. For instance, maize can be grown as a fodder crop in this country, but it seldom, if ever, perfects its seed, owing to the shortness of our summers. If we trace the distribution of indigenous species of this and other countries, we shall find that each advances as far, and only as far, into higher latitudes or into elevated regions as it finds the amount of heat required to complete its growth and ripen its seed. From this we learn how important it is that the cultivation of those farm crops alone, which from experience have been found best adapted to our soil and climate, should be attempted. Of course in gardens where extra care and attention can be given to each kind of plant, this caution may be to a great extent neglected. As a rule, a seasonable amount of heat is best suited in this country to the majority of our farm and garden products. That is to say, a gradual rise in temperature from the middle of January to the middle of July, and as steady a decline until the coldest period is again reached, would best meet their requirements. But, unfortunately, we can seldom count upon such favourable conditions being maintained for more than a few weeks at a time, the general tendency being at any season towards too great or too little warmth. Most of our field crops, with the exception of clovers and grasses, are annuals; whereas most of the plants grown in the garden excepting the kitchen garden are perennials, which require rest at some period of the year, and this, with few exceptions, they obtain during the winter months. Knowing as we do, how the atmosphere receives its warmth, not only from the direct influence of the sun, but from the heat it obtains from the ground, it will be readily understood how greatly the surface soil, particularly uncropped soil, becomes heated above that of the air. It is, however, not only the surface soil which becomes heated, for the warmth thus obtained descends to a considerable depth in the ground. So that the subsoil in this way becomes a storehouse of heat for plants to draw upon during the comparatively sunless period of the year; while it likewise serves by its lower temperature to keep their roots from becoming unduly stimulated during the summer months.

From Fig. 3, p. 62, it will be seen that at 1 foot deep a clay soil—taking the year as a whole—is rather colder than the air; a sandy soil decidedly warmer, while a chalk soil is generally about the same

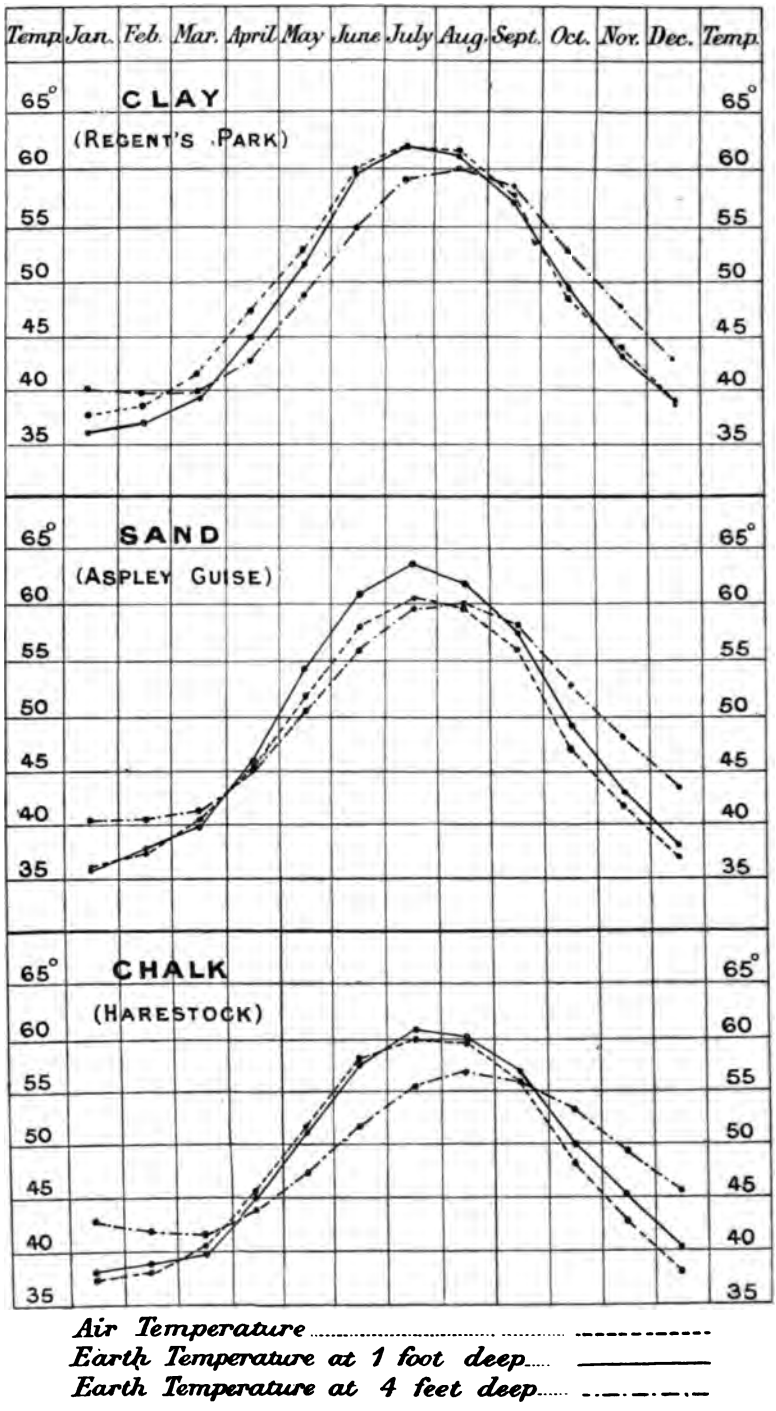


FIG. 3.—Mean Monthly Temperature of the Air and of the Earth at 1 foot and 4 feet deep, for the 14 years 1883-96.

temperature as the air. At 4 feet deep it will be observed that the ground is in all three cases cooler than the air during the period when most plants are in active growth (April—August), and warmer during the remaining seven months. These differences are greatest with a chalk soil; less with a clay soil; and least with a sandy soil. In fact, the soil last named is at 4 feet deep but little cooler than the air throughout a great part of the five warm months above mentioned, although decidedly warmer during the rest of the year. The greater the depth below the surface the more slowly are the changes above ground felt. For instance, taking 1 foot deep as representing the soil and 4 feet deep the subsoil, the former, like the air, is warmest in July; whereas at the depth of 4 feet the warmest month is August. Again, Mr. Symons has shown that at 1 foot deep the ground is coldest, as a rule, not during the night, but at 9 a.m., and warmest, not at mid-day, but at 9 p.m.; whereas at 4 feet deep the changes take place so gradually that there is no appreciable difference at any hour. It was found by Dr. Buchan, when discussing the temperatures of light and heavy soils, "that light soils are subject to a greater degree of frost near the surface than strong clay soils, but that frosts do not penetrate so far down into light soils as into strong clay soils, the explanation being that light loose soils are worse conductors of heat than strong clayey compact soils."

Investigations on the Continent appear to have shown that the rate of progress made by any crop is governed in a great measure by the duration or rather accumulation of temperature above or below the point at which active growth begins and is maintained. This critical point varies with different plants, but the Meteorological Office in its publications has adopted 42° as a sufficiently close approximation for most farm crops in these latitudes, and employs the method devised by Sir R. Strachey, F.R.S., by means of which the variations from this base are determined. Following the nomenclature adopted in the case of the "foot-pound," Gen. Strachey introduced the term "day-degree," by which is signified the continuance throughout 24 hours of an excess or defect of one degree from this base temperature of 42°. The calculations are made as follows. Suppose the minimum temperature of the air on any day to be 50°, the maximum 70°, the mean 60°. Since the temperature never fell so low as 42° it is clear that it must have been effective as regards growth throughout the entire day; and since the mean for the 24 hours was 60° it is also obvious that, if the base temperature of 42° be deducted from that value, the difference + 18° will represent the accumulated amount of this effective temperature. On the other hand, had the readings throughout the day been below the base temperature the difference between the mean and 42° would show a defect of so many day-degrees. In cases in which the temperature varies on both sides of the base the accumulated value is obtained by using a small factor.

Table I., kindly placed at my disposal by Sir Henry Gilbert, F.R.S., will give a very good idea as to how far such accumulated temperatures may be relied upon to furnish approximately correct results in this country. Those given in the lower part of the Table are derived from the mean of the Meteorological Office estimates of daily excess at all the stations in England East and in the Midland Counties. In the first column the calculations date as in the *Weekly Weather Reports* from January 1; in

the second from February 1; in the third from March 1; in the fourth from April 1; in the fifth from the period when the crop appears above ground; and in the sixth from the same period, but omitting those days which are too cold to allow of any progress being made. It will be noticed that, however calculated, the difference between the least and the greatest amount of accumulated heat required at Rothamsted in any

TABLE I.—THE WHEAT CROP AND ACCUMULATED TEMPERATURES. AGGREGATE EXCESS OF DAILY MEAN TEMPERATURE ABOVE 42° F. (or 5°·55 C.) FROM FIXED DATES, OR FROM COMMENCEMENT OF ACTIVE ABOVE-GROUND GROWTH TO DATE OF HARVEST AT ROTHAMSTED.

YEARS.	Fahrenheit Degrees.						Centigrade Degrees.					
	From Jan. 1	From Feb. 1	From Mar. 1	From April 1	From period of active growth	From period of active growth after a check	From Jan. 1	From Feb. 1	From Mar. 1	From April 1	From period of active growth	From period of active growth after a check
According to Records of Monthly Mean Temperature at Greenwich.												
27 years, 1852-78 Max.	2183	2183	2183	2183			1213	1213	1213	1213		
27 years, 1852-78 Min.	1864	1845	1845	1808			1036	1025	1025	1004		
27 years, 1852-78 Mean for 27 yrs.	2023	2018	2004	1981			1124	1121	1113	1100		
According to Records of Daily Mean Temperature at Greenwich.												
6 years, 1871-76 Max.	2285	2259	2181	2123			1269	1255	1212	1179		
6 years, 1871-76 Min.	2064	2015	1985	1875			1147	1120	1103	1042		
6 years, 1871-76 Mean for 6 yrs.	2189	2143	2098	2008			1216	1190	1166	1116		
According to Meteorological Office Estimates of Daily Excess.												
1878	1999	1950	1864	1768	1999	1950	1111	1083	1036	982	1111	1083
1879	1990	1990	1962	1881	1990	1961	1106	1106	1090	1045	1106	1089
1880	1995	1976	1899	1744	1976	1976	1108	1098	1055	969	1098	1098
1881	1816	1814	1804	1699	1814	1804	1009	1008	1002	944	1008	1002
1882	2018	1968	1891	1703	2026	1966	1121	1093	1051	946	1126	1092
1883	1790	1743	1665	1628	1772	1645	994	968	925	904	984	914
1884	1847	1757	1687	1561	1847	1686	1026	976	937	867	1026	937
1885	1774	1752	1674	1601	1774	1696	986	973	930	889	986	942
1886	1924	1915	1915	1816	1915	1915	1069	1064	1064	1009	1064	1064
1887	1816	1789	1736	1679	1812	1729	1009	994	964	933	1007	961
1888	1862	1834	1824	1790	1862	1799	1034	1019	1013	994	1034	999
1889	2016	2000	1977	1882	2013	1977	1120	1111	1098	1046	1118	1098
1890	1947	1853	1842	1715	1947	1842	1082	1029	1023	953	1082	1023
1891	1834	1808	1744	1676	1834	1706	1019	1004	969	931	1019	948
1892	1875	1847	1807	1749	1871	1807	1042	1026	1004	972	1039	1004
1893	2028	2007	1952	1728	2028	1964	1127	1115	1084	960	1127	1091
1894	1934	1890	1819	1645	1932	1838	1073	1050	1011	914	1073	1021
1895	1716	1716	1716	1607	1716	1716	953	953	953	893	953	953
Maximum	2028	2007	1977	1882	2028	1977	1127	1115	1098	1046	1127	1098
Minimum	1716	1716	1665	1561	1716	1645	953	953	925	867	953	914
Mean for 18 years	1899	1867	1821	1715	1896	1832	1055	1037	1012	953	1053	1018

year to complete the growth of wheat and ripen the grain, was in all cases about 300°, or about one-sixth of the total mean value for the 18 years. This appears to me a very large range indeed, and shows that such calculations can only be regarded as rough approximations, at all events as far as the leading cereal crop in this country is concerned.

Frost.

As farmers and gardeners invariably speak of temperatures below 32° as so many degrees of frost, and as such low readings have often a distinct influence on plant life, I have thought it well to devote a few paragraphs specially to their consideration.

In the first place, there are many kinds and degrees of frost, each of which has a different effect on plants which are not perfectly hardy. For instance, there is the moderate frost of short duration, which as a rule acts beneficially, by giving a wholesome check to growth during a dangerous period of the year. There is the prolonged winter frost, which, if not too severe, does more good than harm to vegetable life, while greatly benefiting the soil by its disintegrating effect. On the other hand, there occasionally occurs a frost extending over many weeks, when extremely low readings are registered, during which all but the hardiest plants suffer severely, while many of the more delicate species are killed outright. During the present century there have been in the neighbourhood of London, eight of these memorable frosts, the average interval separating them being about 10 years. They, however,

TABLE II.—Prolonged Frosts in the Neighbourhood of London during the present Century.

Period.	Days' Duration.	Temperature.				Days.	
		Mean Max.	Mean Min.	Mean.	Absolute Min.	Max. 32° or below.	Min. 20° or below.
		°	°	°	°		
1813-14. Dec. 26—Feb. 5 .	42	33·0	21·5	27·3	8·0	20	16
1838. Jan. 5—Feb. 23 .	50	32·9	24·9	28·9	-4·0	19	9
1855. Jan. 10—Feb. 25 .	47	34·8	24·5	29·7	11·1	15	12
1860-61. Dec. 15—Jan. 19 .	36	34·9	24·8	29·9	8·0	9	8
1879. Nov. 14—Dec. 27 .	44	37·2	24·7	31·0	13·7	6	4
1881. Jan. 7—26 . .	20	31·8	22·1	27·0	12·7	12	10
1890-91. Nov. 25—Jan. 22 .	59	33·5	25·0	29·3	12·0	27	10
1894-95. Dec. 30—Mar. 5 .	66	36·9	26·7	31·8	6·9	17	11

occurred so very irregularly that Table II. cannot be taken as any guide whatever as to when the next prolonged frost may be expected; in one case the interval between them being only one year, whereas in another it amounted to 24 years.

Then there are wind frosts, which although not generally so low in temperature as in the ordinary radiation frosts, are much more trying to vegetation, as not only are the upper surfaces of the leaves chilled, but the whole plant is enveloped in a swift-flowing current of cold air. A frost in the winter has to be very keen indeed to inflict any serious

injuries, but late spring frosts are greatly to be feared, as most plants are then in active growth, and covered with young and tender foliage. It is these frosts which, by destroying the blossoms and fruit-buds, so often destroy also all prospect of what would otherwise have been an abundant fruit crop. If their leaves be dry, plants will frequently escape injury from a frost, which if it had been preceded by rain would have greatly crippled them.

Much also depends upon the duration of the frost as well as on the lowness of the temperature. As an instance of this I may state that on the nights preceding October 6 and 7, 1897, 5° and 8° of frost were respectively indicated by the thermometer exposed on the lawn at Berkhamsted. On the first of these nights my dahlias, which were growing within a few yards of this thermometer, were not the least injured; whereas on the second night, when there were only 3 more degrees of frost, the whole of the upper part of the plants was completely killed and their flowering ruined for the season. I could not understand this at first, as the weather on both nights was apparently similar in all other respects, until I examined the thermograph trace, when I found that the coldest period on the first night lasted only about a quarter of an hour, whereas on the second night it lasted for six hours.

In protecting delicate plants in a severe winter frost, the covering requires to be very substantial to be of any real service, but it is surprising how slight is the protection necessary in most instances in the case of late spring, or early autumn frosts. As often as not it is the exposure of the plants to sunshine on the morning succeeding these brief frosts which is answerable for the injuries attributed to it. The effect of very low temperatures on vegetation and also of quick thawing is thus explained by Dr. Vines in his *Student's Text-book of Botany*:—

> When a part of a plant which contains a large proportion of water is exposed to a low temperature, a portion of the water contained in the cells escapes from them, and becomes frozen on their surface, the whole tissue at the same time contracting; the water does not freeze in the interior of the cells. The water which has thus escaped and frozen forms an incrustation consisting of a number of elongated ice crystals arranged side by side. This ice is very pure, for the substances in solution in the cell-sap remain behind in a more concentrated form. It has been ascertained that this formation of ice is, in itself, not necessarily fatal in all cases. If the frozen part be slowly thawed, the cells may gradually reabsorb the water and so return to their previous normal condition. If, however, the frozen part be quickly thawed, the cells cannot absorb the water sufficiently rapidly; it therefore either collects in the intercellular spaces, causing discoloration and decay, or it runs off and evaporates, so that the part dries up.

Spraying plant foliage with water in order to thaw it before the sun is up, will be often found an effectual remedy against injury when late spring frosts occur. In the case of low growing plants, straw, or any similar light litter, may with advantage be distributed lightly over them on the previous evening, whenever an unusually keen frost threatens, and a valuable plant or crop may in this way be saved. In the case of individual plants, I have found sprigs of heather much more serviceable than bracken, as they do not hold the damp, and are more easily

applied. Early potatoes which are just above the ground will often escape injury if covered with single sheets of newspaper.

Rain.

The influence of rainfall on vegetation stands second only to temperature, for each kind of plant not only requires a certain degree of warmth, but also a certain degree of moisture, in order to perform its various functions in the most perfect manner. There are two classes of farm crops, the requirements of which, as regards rainfall, differ considerably. Taking one year with another, the fall of rain in these islands more than meets the wants of the cereals as regards moisture, while there is often too little and seldom too much for the roots and grass crops. In times of drought, plants have to rely on the water in the subsoil, and consequently the deeper-rooted corn crops are less injuriously affected, when once established, than the comparatively shallow-rooted turnips, and many of the grasses. This leads us to consider the passage of rain into the soil, known as percolation. Of the moisture received from the clouds, the greater part during the winter half of the year descends permanently into the ground, whatever be the crop growing upon it. But it is otherwise during the summer half of the year, for even on uncropped ground only about one-fourth of the total rainfall for these six months finds permanent lodgment in the subsoil, the other three-fourths being carried into the atmosphere by evaporation. On land thickly covered with vegetation, like permanent pasture, it is only in times of exceptionally heavy rains that at this season any water at all has a chance of penetrating the soil to any depth, the whole being taken up by the herbage or evaporated. It may be mentioned in passing that it was found at Rothamsted that by the application of nitrate of soda to pasture land, the grass became deeper rooted, and was thus enabled to withstand without serious injury even the long spring and early summer drought of 1870. The question of percolation becomes one of considerable importance when we consider how the fertility of land is lessened when the drainage is excessive. This is evidenced by the Rothamsted experiments, where the soil has been shown to be richest in nitrates after the period of least percolation; that is to say, between July and October, and poorest after the winter, when the drainage is greatest—say between April and June. The greatest loss of these valuable nitrates consequently occurs during unusually wet autumns and winters, whereas during a dry and sunny spring and summer the soil increases most in fertility. It was formerly supposed that land left fallow during the winter was benefited thereby, but it is now known that the soil retains its nitrates much more effectually if covered by a crop of some kind, and more particularly will this be the case if the winter prove a wet one. To put the matter in another way, if it were certain that any winter would be dry it might be advisable to apply nitrogenous manures to wheat crops in the autumn, but if certain to be wet their application should undoubtedly be deferred until the following spring. Winter rains may not be necessary for the immediate wants of either farm or garden crops, but they are invaluable in allowing a plentiful supply of moisture to be stored up in the subsoil for the future well-

being of these crops—to say nothing of the requirements of fruit and other trees and shrubs with their deeper roots and dense foliage.

From Fig. 4 it will be seen that in an average November three-fourths of the rainfall descends permanently into the ground, the remaining quarter being evaporated, while the loss of nitrogen is greater than in any other month in the year, amounting to 6 lbs. per acre, which is equivalent to 39 lbs. of nitrate of soda per acre. In an average May the conditions are reversed, as less than one-fourth of the

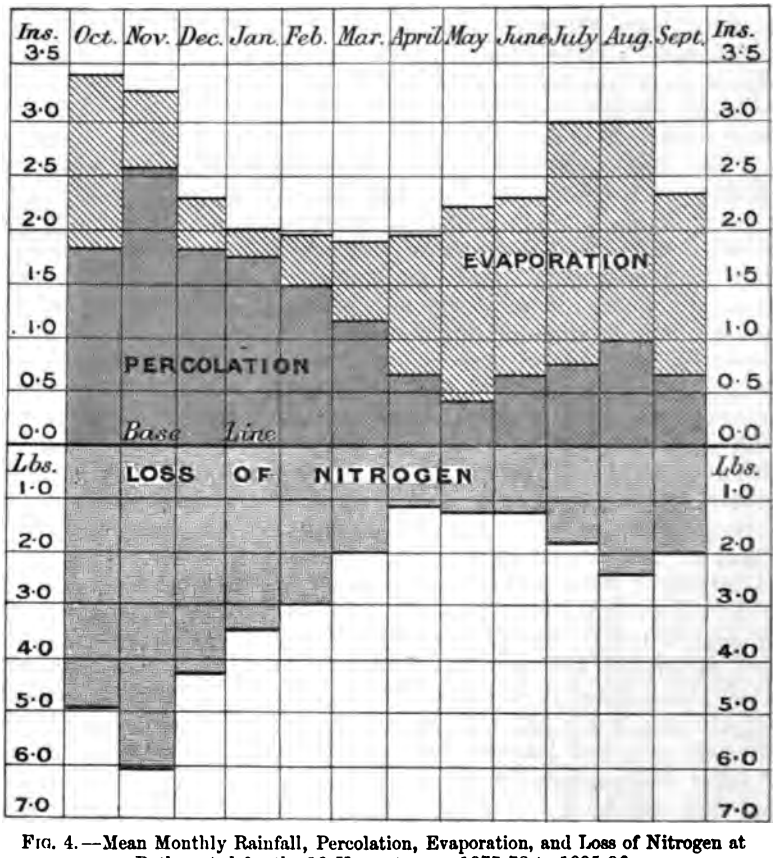


FIG. 4.—Mean Monthly Rainfall, Percolation, Evaporation, and Loss of Nitrogen at Rothamsted for the 19 Harvest years 1877-78 to 1895-96.

total rainfall passes into the ground, leaving the remaining three-fourths to be evaporated, while only about 1 lb. of nitrogen per acre, equivalent to 7 lbs. per acre of nitrate of soda, is lost. It will be noticed how closely the quantity of nitrogen washed out of the surface soil varies with the percolation or the amount of rain-water draining into the subsoil.

It is during the late spring and early summer, when most plants are growing more rapidly than at any other period of the year and evaporation is greatest, that the want of sufficient rain is most keenly felt. On the other hand, continued wet during the same period is also

undesirable, principally because a long continuance of rainy weather at this season invariably means in these islands also a long continuance of unseasonably cold, humid, and sunless weather.

The great difficulty in treating of this question of rainfall consists in the different effect it has on different soils and subsoils. To take two extreme cases, heavy clays which require but a moderate amount of rain, and deep sandy or gravelly soils which can scarcely at any season have too much. Indeed, it has been said that if as much rain fell on the heavy clay lands of England as on the friable soils of Ireland, the most productive wheat soils would be comparatively barren.

It must not be forgotten that the character of the rainfall in any locality or at any period of the year is a matter of almost equal moment with the quantity. For instance, after a dry period the fall of an inch of rain on a single day during the first week would not be nearly as beneficial as if four falls of a quarter of an inch each were equally distributed over it. In the foregoing remarks I have dealt only with growing crops, but of course the character of the weather at the times of haymaking and harvest is of almost equal importance.

Droughts.

As I have separated frosts from temperature for consideration by themselves, it may be well in the same way to say a few words here as to droughts, as distinct from rainfall. Different farm crops, as previously stated, vary considerably as to their powers of enduring a long continuance of dry weather, and this power depends, as a general rule, upon the nature and depth of their roots. For meteorological purposes Mr. Symons' definitions of "absolute" and "partial" droughts have proved most serviceable, but, from an agricultural and horticultural point of view, they are often likely to be very misleading. For, when the ground has once become dry on the surface and to the depth of several inches, a fall of a tenth of an inch of rain once a week, which would soon bring to an end even a "partial drought," would prove of no service at all to vegetation generally, beyond temporarily cooling and moistening the air. Indeed, it would do more harm than good on certain kinds of soil by caking the surface, and thus tending to increase evaporation from it afterwards. What farmers would say under such circumstances would be "these light rains do no good at all, what is wanted is a good, steady rain for twenty-four hours." At Rothamsted during the drought of 1870, which extended over the months of April, May, June, and July, it was found that the mixed herbage of permanent meadow-land suffered very much more than either wheat or barley; and the spring-sown barley suffered very much more than the autumn-sown wheat.

I have given on p. 70, in Tables III. and IV., a list of the most trying droughts and persistent rains which have occurred during the present century in the neighbourhood of London, at that period of the year when the growth of plants is most active.

When compiling these Tables, it soon became apparent that during the above four months dry periods were of far greater frequency and severity in this country than wet ones. Indeed, had the same limits as

to duration been adopted in the case of the wet periods as in the case of the droughts, there would have been only two of the former left to chronicle.

TABLE III.—Prolonged Droughts during the Spring and Summer at Greenwich since 1815.

Year.	Period.	Length of Drought.	Rainy Days.	Rainfall.
		Days.		Ins.
1818	May 19—Sept. 1 . .	106	13	1·36
1825	May 29—Aug. 2 . .	66	4	·84
1834	April 3—June 3 . .	62	12	1·01
1844	Mar. 15—June 23 . .	101	11	·53
1854	Feb. 24—April 27 . .	63	9	·69
1870	Mar. 27—June 30 . .	96	15	1·14
1887	June 4—Aug. 15 . .	73	11	1·37
1893	Mar. 6—July 3 . .	120	24	1·59
1895	April 28—July 16 . .	80	19	1·08

TABLE IV.—Continued Wet Periods during the Spring and Summer at Greenwich since 1815.

Year.	Period.	Length of Wet Period.	Rainy Days.	Rainfall.
		Days.		Ins.
1828	July 4—Aug. 14 . . .	42	27	10·04
1830	May 21—July 20 . . .	61	34	9·27
1838	May 28—July 6 . . .	40	29	6·78
1848	July 20—Aug. 31 . . .	43	38	6·10
1860	July 16—Aug. 30 . . .	46	34	6·24
1878	April 1—June 30 . . .	91	51	13·17
1879	May 23—July 24 . . .	63	43	10·39
1888	June 26—Aug. 6 . . .	42	34	10·76

In the garden, plants are less at the mercy of dry weather than in the fields. At all events they should be, for even in the case of a porous soil, much may be done either by frequent watering, by mulching, or by hoeing, to enable them to withstand a long continuance of dry weather. In addition to which, the liberal application of farmyard manure will be found greatly to increase the moisture-holding capabilities of the ground, if persevered in year after year. Large fruit trees, like standard apple trees, do not appear to feel dry weather as soon as more shallow-rooted plants, but the crop is often injuriously affected in the autumn, after a spring and summer drought, by the want of sufficient moisture in the subsoil, at a period when the fruit should be swelling, and the flower-buds forming for the following season. Droughts are very detrimental to lawns, and especially to those on poor soil, as so many of the weeds growing on them stand dry weather much better than the grasses, and consequently, under such conditions, gain ground more rapidly than they otherwise would.

In 1884 I carried out the following experiment in order to ascertain the effect of mulching (covering the soil with half-decayed manure, leaves, etc.) upon the moisture and temperature of the ground beneath

it. I had two percolation gauges, each 3 feet square and 3 feet deep, that had been sometime previously filled with the ordinary soil of my garden at Croydon, which was of rather a light and porous character. On the soil in one gauge was placed a layer 3 inches deep of half-decayed manure, while the surface of the other gauge was left uncovered. Once a week the mulching was loosened with a fork, and the soil in the other gauge hoed to the depth of about an inch. Taking the five months ending August, when the growth of plants is most active, it will be gathered from Table V.—(1) that the mulched soil remained more uniformly moist than that unmulched; (2) that it was also more equable in temperature, being slightly warmer at night and decidedly cooler during the daytime. There were, I find, no fewer than 68 days during the same five months when no measurable quantity of rain-water passed through the unmulched soil, but on no occasion did percolation altogether cease in the case of the mulched soil. There are two important points to be borne in mind as to the application of mulching:—(1) it should not be put on, in any case, earlier than May, as it keeps the ground cold at a time when warmth is most needed; (2) it should never be too deep or too close in texture, or it will often do more harm than good by excluding light and air from the roots of the plants round which it is placed.

TABLE V.—Showing the Effect of 3 inches of Mulching on Percolation, Evaporation, and Temperature.

1884.	Soil with mulching above or below that unmulched.					Air Temperature.		Rainfall.	
	Percolation.	Evaporation.	Earth Temperature at 1 foot.						
			9 a.m.	3 p.m.	9 p.m.	Mean Max.	Mean Min.	Amnt.	No. of Days.
	Ins.	Ins.	o	o	o	o	o	Ins.	
January	−·11	+·11	+0·5	0·0	+0·1	48·1	39·4	2·58	16
February	+·39	−·39	+0·7	0·0	+0·1	47·9	37·4	1·78	13
March	+·51	−·51	+0·5	−0·5	−0·6	51·1	37·7	1·46	9
April	+·11	−·11	+0·6	−0·4	−0·7	52·4	37·1	1·32	13
May	+·07	−·07	0·0	−1·6	−2·0	63·1	44·0	0·56	10
June	+·05	−·05	−0·2	−1·2	−1·9	66·1	48·8	1·90	9
July	+·17	−·17	+0·2	−1·2	−1·9	71·8	53·9	1·59	16
August	+·17	−·17	+0·3	−3·7	−2·2	75·5	52·9	1·07	8
September	+·02	−·02	+0·6	−0·6	−0·6	67·0	51·6	2·38	15
October	+·16	−·16	+1·1	+0·5	+0·3	56·0	41·9	1·20	12
November	+·09	−·09	+1·2	+0·7	+0·6	47·3	36·2	1·57	12
December	+·04	−·04	+0·7	+0·4	+0·1	45·5	37·0	2·28	16
Sums	+1·67	−1·67	...	...	...	...	...	19·69	149
Means	...	...	+0·5	−0·6	−0·7	57·6	43·2	...	...

Snow.

A deep fall of snow during the winter months is always welcomed both by farmers and gardeners. It keeps the ground comparatively warm and steady in temperature, while affording the most efficient

safeguard against severe frost to all plants covered by it. A slight coating is also often of considerable service, even to such a hardy plant as young wheat, owing to the protection it affords from keen frosts and biting winds.

Sunshine.

The part played by sunshine in the growth of crops is very considerable, whether we regard the influence upon them of the less refrangible rays of the spectrum, or those of the highly refrangible rays. It has been truly said that heat, water, and soil can be artificially supplied to plants, but no light so suitable for vegetable life as sunlight. Almost every crop is more dependent upon sunshine at some particular period of the year than any other. For instance, corn at the time of ripening, the grass crops in the spring, the roots in the autumn, the fruit crops when approaching maturity, and so on. In the spring months it is sunshine rather than rain that is mostly wanted: sunshine to warm the ground, for without this, rain is of little service either for the germination of seeds or the growth of plants. Again, it has been found at Rothamsted that, while certain seasons may favour the mixed herbage of grass lands, in so far as luxuriance of growth is concerned, it is in others, no doubt during the more sunny ones, that this herbage becomes properly matured. So that in the latter case, although the yield may not be so great, the quality is very superior. Corn crops are likewise similarly influenced, some seasons favouring growth, while others favour more particularly the perfecting of the grain and its maturation. In gardens, the difference in the character of the shoots made during a wet and cloudy spring and early summer is very distinct from that made in a period of almost continuous sunshine. Abundant sunshine in the autumn is also of the greatest value to a large class of hard-wooded plants and trees, and especially to fruit trees, for without this there will be little prospect of the growths of the current year becoming satisfactorily matured before the winter sets in.

There has been found to be a very close connection between the quantity of watery vapour exhaled by leaves and the degree of sunshine to which they are exposed. This being the case, and knowing as we do the important part played by this function of transpiration, as it is termed, in building up the structure of plants, it will readily be understood how much the character of their growth must be dependent upon whether any particular season is unusually sunny or the reverse.

Wind.

Wind has been aptly styled the vehicle of climate, and is said to make the weather. In this country there are two main currents of very different types. The first and most prevalent is that from off the Atlantic, which comes laden with moisture, and is comparatively cool in summer and warm in winter; while the other reaches us from the wide continent to the north-east and east, and is considerably drier, and brings our hottest summer and coldest winter temperatures. Of the latter, the North-easterly winds, so prevalent during the spring months, are the most trying to vegetation on account of their cold and harsh

character. It is principally on account of these North-easterly winds, which usually occur when the blossoms of fruit trees are opening, and the late frosts which often visit us about the same time, that the site for an orchard or fruit-garden requires selecting with considerable care. A gentle slope facing south-west would not only protect the trees to a great extent from the most trying winds, but the fall in the ground would allow of the cold air flowing past them into the valley below on frosty nights. Exceptionally high winds only occasionally, as at the

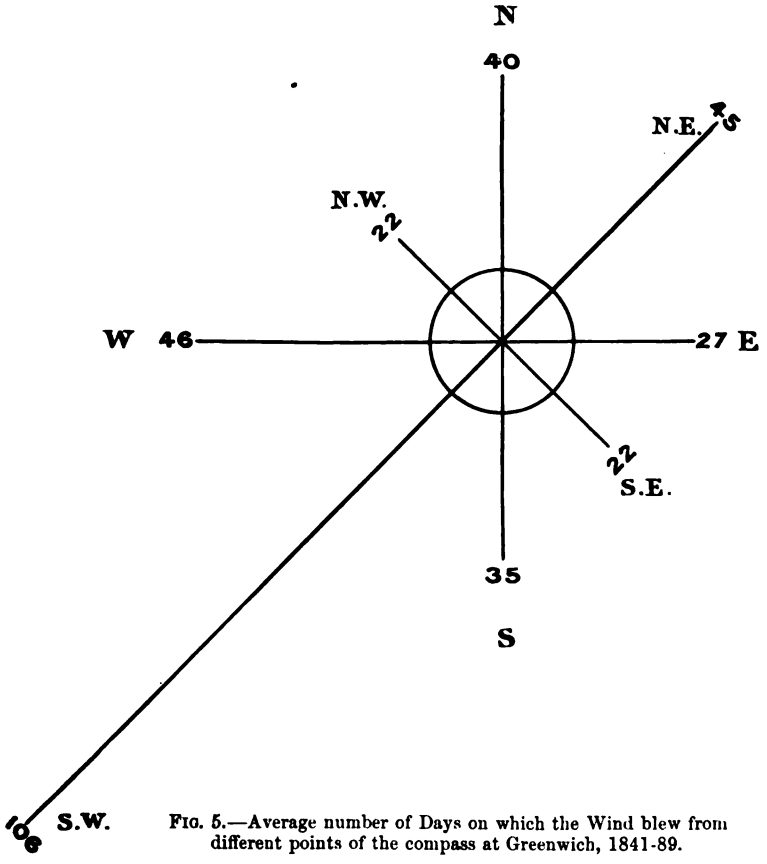


FIG. 5.—Average number of Days on which the Wind blew from different points of the compass at Greenwich, 1841-89.

blossoming time of the cereals, or in "lodging" the corn crops just before harvest, do serious injury on the farm. In gardens, particularly those situated in exposed positions, however, much damage is often done during a gale by boughs being wrenched off trees and shrubs, by fretting the leaves against the twigs and branches, and in other ways. The necessity of placing firm stakes to all plants requiring them is too often overlooked until a considerable number of plants have been overturned or broken off. Winds are also frequently the means by which the down of thistles, and other light seeds, are conveyed from an ill-farmed to a well-farmed field adjoining.

Fig. 5, p. 73, will give a good idea as to the relative prevalence of different winds in this country. It will be seen that by far the most prevalent wind is that from South-west, the direction next favoured being West, and that the two winds taken together monopolise 152 days, or something like half the year. These are followed by North-easterly and Northerly winds, with 85 days between them; while the points least favoured are South-east and North-west. The circle in the centre of the diagram represents the number of calms in the year, viz. 22.

Wheat.

From remote times these islands have never been considered as good for corn-growing as for feeding and grazing stock. The fact is, wheat, being a native of warmer climes, requires a higher summer temperature than our climate usually affords. It is stated that in no part of Europe where wheat is grown are the summers so cold. Our average summer temperatures are also said to be almost the minimum for bringing this cereal to perfection, and that therefore a deficiency of a few degrees in mean temperature at this season must always be a great drawback to its successful cultivation. If this be the case, the difficulty becomes even greater on elevated lands, where the mean summer temperature is lower and the growing season shorter. Wheat cannot be grown as far north as either barley or oats. In Ireland, however, it is not any limits of temperature that prevents this cereal from being largely grown, but its unfavourable soil and humid climate. Even in England the yield is, as a rule, least in a rainy season and best in a dry one; but if the dryness be prolonged, the straw is neither as tall nor as vigorous. There is one important advantage which wheat possesses over other grain crops usually grown in this country, in that it may be sown in autumn when other cereals would often perish. There are two critical periods when fine weather is of the greatest importance: the first when it is coming into flower, and the other at harvest time. Corn has always been regarded as an exhausting crop, but this has been found at Rothamsted not to arise from cereals taking more nourishment out of the land than other crops, but to be mainly owing to their short period of active growth and the long time the ground is bare, and the consequent greater loss of nitric acid through drainage. On one plot at Rothamsted wheat has been grown continuously without any manure for 54 years, and yet in an exceptionally favourable season this plot will yield even now a better average crop than the average wheat lands of the world, or even than the rich prairie soils of America. This fact shows perhaps more clearly than any other that could be given the powerful influence that the weather has on this crop.

The accompanying diagrams, Figs. 6 and 7, illustrate in a graphic manner the kind of weather which most favours, and on the other hand that which least favours, the growth of wheat in this country, at all events as regards heat and moisture.

The six best years and the six worst years for wheat at Rothamsted, during a long interval, were selected, and the average weather conditions as regards temperature and moisture ascertained.

The results show that the good years were, when taken together,

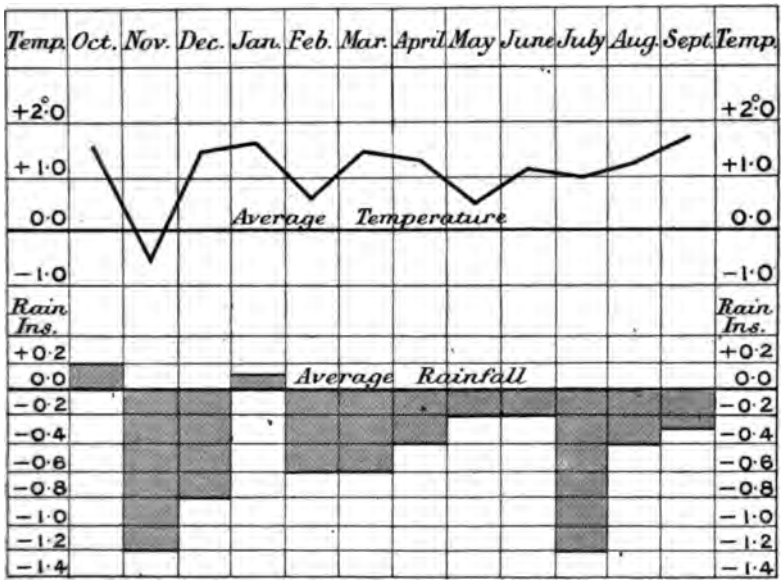


FIG. 6.—Mean Monthly Variation from the average in Temperature and Rainfall for the six years when the Produce of Wheat was highest at Rothamsted.

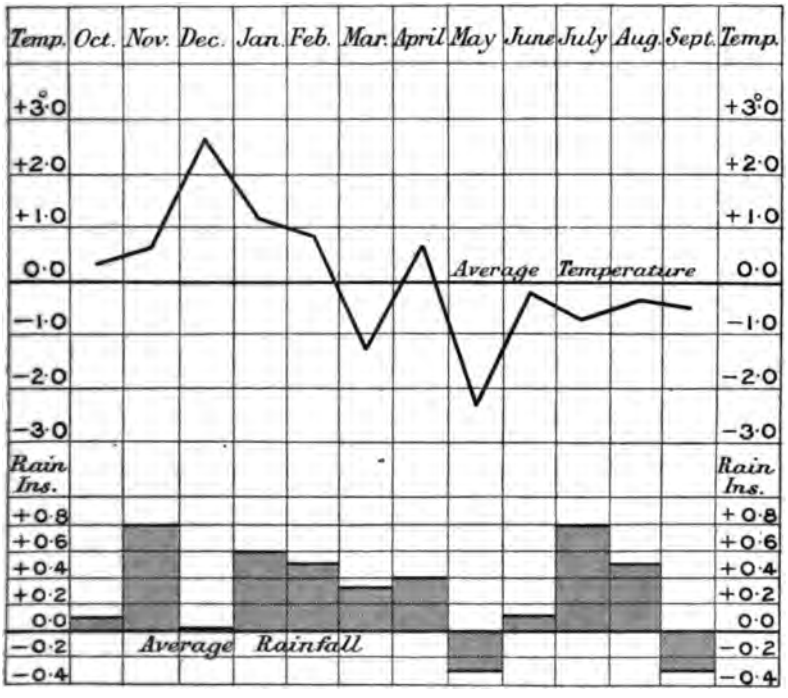


FIG. 7.—Mean Monthly Variation from the average in Temperature and Rainfall for the six years when the Produce of Wheat was lowest at Rothamsted.

warm and dry throughout, while the bad years are distinguished by their generally low temperatures and persistent falls of rain.

Barley.

This grain is better suited than any other for growing near the northern limit of the corn-growing belt. In fact, some varieties will thrive where the climate is too cold and the summers too short to bring to perfection either wheat or oats. It can also be grown with advantage in warmer localities than other cereals. It succeeds best, as a rule, in the east of England, although in dry seasons it suffers much more from drought than wheat, owing to its greater dependence on surface moisture. Its chief requirements as regards weather are a genial showery spring and a moderately rainy summer. On the other hand, the produce is low when there is either too much or too little rain.

Oats.

This is a crop well suited to the moister districts of the British Isles, consequently we find it the leading cereal in Scotland and also in Ireland. In Ireland ten acres of oats are said to be cultivated to about one of any other grain crop. It can also be grown with advantage at a greater elevation than either barley or wheat. On the other hand, it thrives worse than either where the climate is warm and the summer temperature high. In consequence of its density on the ground, this crop absorbs a large amount of water.

Roots.

Taking the root crops as a whole, they are most luxuriant in the more humid districts of these islands, and, unlike corn, delight in a cool, wet summer, provided the autumn be mild and sunny to mature them. Few of the roots grown in this country are sufficiently hardy to withstand severe weather, so that it becomes important they should be stored in safe quarters as soon as possible after they have completed their growth and are sufficiently ripened and before the winter frosts set in.

Beans and Peas.

The beans sown in autumn are found, as a rule, to produce the best crops, provided the young plants escape injury from cold during the winter. They have this advantage at harvest time over corn, in that they can be cut in bad weather. Peas make their best growth in moderately wet summers, and are among the first crops to suffer from a continuance of dry weather.

Pasture Grass.

This is, after all, by far the most extensively grown crop in these islands, and the one most suitable for the climate. It is the only perfectly hardy farm crop that we grow; and although it soon shows the effects of drought, such droughts never appear to permanently injure it, for on the return of wet weather it is soon as green and flourishing as ever. As showing its extreme hardiness and ability to withstand ill-usage as compared with some other native plants, I may state that when the lawn at the side of my house was covered with

three inches of snow on February 3, 1895, in order to make a skating rink there the snow was rolled and afterwards watered, and the grass remained covered with the coating of ice thus formed for the next three weeks. In the following summer I noticed that although the grass was as luxuriant as ever, not a single weed was to be seen on that particular part of the lawn, which like the rest of it had previously been thickly studded with dandelions, plantains, daisies, and other weeds. Even now, three years afterwards, it is easily to be seen, by its comparative freedom from weeds, where the skating rink had been made.

Comparing the weather influences that have proved most favourable and least favourable to the hay crop in the same way that we have done those affecting wheat, it will be noticed (Figs. 8 and 9) that there was no very great difference as regards temperature taking the averages for the six best and the six worst years at Rothamsted during the growing period except in May and June; but that in the one case (the best years) the rainfall was rather in excess during that period, whereas continued drought is the chief characteristic of the bad years. This is doubtless due to the shallow-rooted character of the crop.

Potatoes.

The great weather enemies of this crop are late spring frosts, and too much rain during the summer months, as the latter favours that fungus popularly known as the "potato disease." This fungus generally makes its appearance towards the end of July, when the temperature is most favourable to its growth, and close, thundery weather seems to induce the disease at once.

Fruit.

Most of our outdoor garden fruits make the most satisfactory growth when the air and soil are moist and warm, but during the ripening period more heat and light and less moisture are required to bring the fruit to perfection, and to properly mature the young shoots, without which the production of fruit in the following year is never likely to prove satisfactory. The most critical period is when the blossoms are setting, for then they are fully expanded and most exposed to the influence of frost and cold winds. For this reason it is unadvisable to plant orchards in valleys or hollows which are so often veritable traps for frost. As different varieties of apples and other fruits vary to a certain extent in their times of flowering, and also in their after-requirements as regards weather, it will be well not to be too restricted in the number of sorts grown, and so ensure as far as possible a good crop on at least some of them, even in the more unfavourable seasons.

Kitchen Garden Crops.

What has been said about the crops on the farm as regards weather applies to a great extent to those grown in the kitchen garden, except during the winter months. At that season, there is little to be seen but young wheat and winter oats in the fields, and grass in the pastures, all three of which are much hardier than any of the crops grown in the garden for the winter supply of green vegetables. Consequently in times of extreme cold the latter suffer severely. The difference in

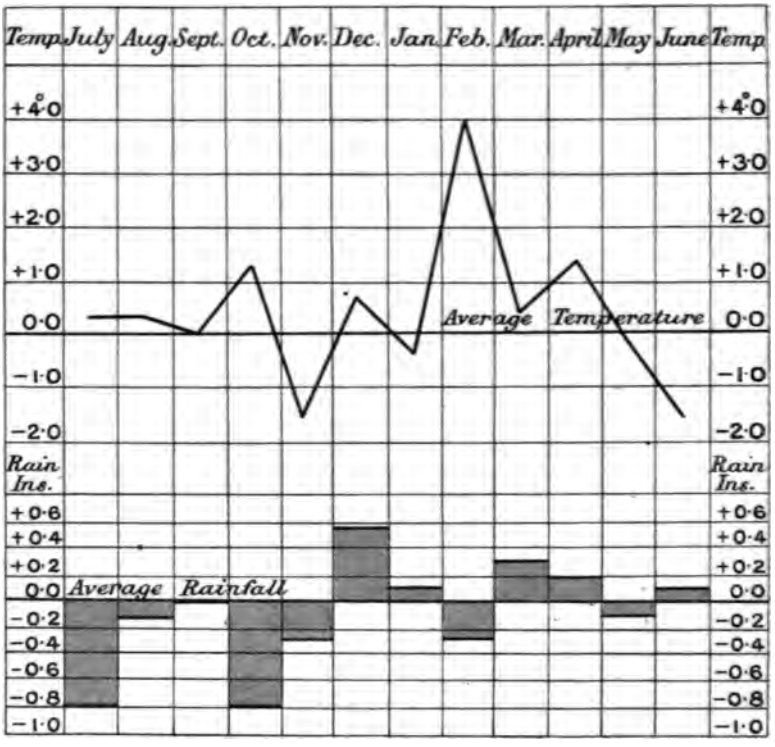


FIG. 8.—Mean Monthly Variation from the average in Temperature and Rainfall for the six years when the produce of Hay was highest at Rothamsted.

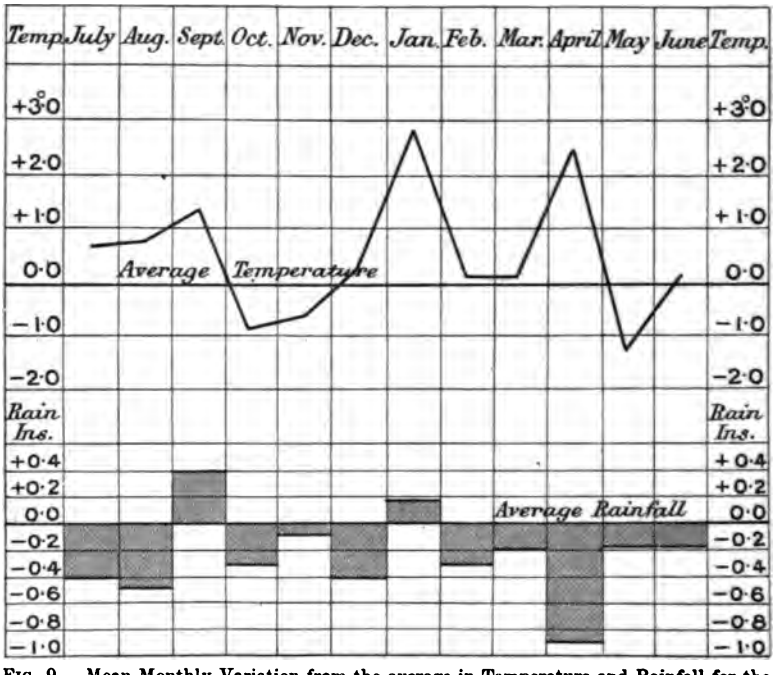


FIG. 9.—Mean Monthly Variation from the average in Temperature and Rainfall for the six years when the Produce of Hay was lowest at Rothamsted.

the prices charged for such vegetables in our large towns after a mild winter compared with those charged after a severe winter will show how great has been the havoc committed in the latter case by frost among them. In other parts of the year, spring and summer droughts may be regarded as most hurtful. As on the farm, so in the garden, one of the first crops to suffer in a dry summer is that of peas.

The Flower Garden.

The numerous plants cultivated for their flowers in gardens differ so greatly in their structure, habit, and times of active growth, that it is impossible within the limits of this address to give anything more than a very slight sketch of the influence of weather changes upon them. For our present purpose they may be roughly divided into three classes, viz. hard-wooded plants, like roses; herbaceous perennials, like the Japanese anemone; and plants sensitive to cold, as dahlias, geraniums, etc.

1. Most of our roses are only half hardy, and consequently have to contend against many weather enemies. Their requirements are best met by a dry and sunny autumn to mature the shoots made during the summer; a moderately cold winter to give them that rest which is so desirable at this season; a frostless spring to preserve their young shoots intact; and a moderately warm and showery summer to bring their flowers to perfection. In order to show how seldom they pass through a whole year without falling victims to some hostile atmospheric influence, I may mention that for twenty years I have written the weather history of the numerous roses in my own garden, and only once or twice during that period have I been able to describe any year as even to a great extent favourable. One of the best years was that of 1897, when the weather was generally propitious, or rather there occurred in no month any weather which was specially unpropitious to their well-being. The above remarks will apply to a great extent to a large number of other garden flowers, shrubs, and trees of similar growth.

2. The next type we have to consider is that numerous class known as "herbaceous plants." These are mostly the wild plants of other countries, which die down to the ground-level on the approach of winter, and throw up fresh shoots in the following spring. The Rev. C. Wolley Dod, V.M.H., a leading authority on this subject, has kindly favoured me with his views as to weather influences upon them. He begins by saying that in his opinion there is no other country in the world where plants from localities and climates so widely different could be so successfully cultivated in the open air as in England. As a rule, plants from New Zealand, the temperate parts of South America, and those from the Rocky Mountains seem to have the greatest difficulty in adapting their growth to the average conditions of English gardens. He mentions some Alpine plants, which, although they can resist Arctic frost, do badly here, because they do not get the rest they require during the winter, and so fall victims to our damp atmosphere. He points out the importance of a dry sunny time in May to ripen spring bulbs after flowering, without which ripening they cannot be expected to bloom freely the following year. He concludes by expressing the opinion, with

which I entirely concur, viz. that a wet summer with alternating periods of sunshine, in other words a showery summer, is the most favourable in all English gardens, even those on a retentive soil, like that of Mr. Wolley Dod's, near Malpas in Cheshire. There are many florist's flowers and other perennials, besides those known as herbaceous, to which the above remarks will almost equally apply.

3. Lastly, we come to plants which are only grown in the open ground during the summer half of the year, like dahlias. Almost every district differs as to how early in the year such plants can be safely planted out, this depending upon the comparative liability of different districts to keen late frosts. Such plants, particularly dahlias and nasturtiums, fall easy victims to the first frost of any severity in the autumn. If I may regard the autumn climate of my gardens at Croydon and Berkhamsted, taken together, as representing approximately that of the home counties, I may state that the earliest date at which dahlias have been killed to the ground in the last twenty-one years has been October 3 in 1888, and the latest December 1 in 1894; the average for the whole period being November 3.

Injurious Insects.

It is often supposed that during very cold winters a large number of insect pests must be killed; this, however, is far from being the case. Indeed, on the contrary, it is usually in a mild, or still more in a fitful, winter that such insects are destroyed wholesale. The fact is, most of them are able to withstand almost any degree of frost as long as they remain in their selected winter quarters, whether these be above or below ground; but with the advent of unseasonably warm weather at this season, they are tempted out of these shelters, and fall easy victims to any sudden sharp frosts that may afterwards occur.

Plant Phenology.

Accumulated temperatures only deal with one element affecting plant life, heat; whereas in noting the times of flowering of native plants, we obtain, as it were, records of the cumulative effect upon them of heat, light, and moisture. As phenological reports are issued by this Society annually, I need but refer briefly here to this branch of its work. Indeed, it is only during the last seven years that the observations have been made on one uniform plan by a sufficient staff of observers to allow of any definite conclusions being drawn from the data collected; while some of the districts into which the British Isles are divided in these reports are even now more or less inadequately represented. Nevertheless, the following particulars may be of interest as showing the relative forwardness of vegetation in those districts where the observations are sufficient to warrant such comparisons being made.

Taking the mean dates for the Midlands, as representing the country as a whole, we obtain the following results for the seven years:—

ENGLAND, THE MIDLANDS, AVERAGE.

England, east,	3 days early.	England, north-west,	2 days late.
,, south,	5 ,, ,,	Ireland, north,	5 ,, ,,
,, south-west,	6 ,, ,,	England, north-east,	9 ,, ,,

So that in England alone there is an average difference of 15 days between the most forward and the most backward districts.

Again, taking the mean dates for the 12 plants on the Society's list coming into flower during the first six months of the year, and confining ourselves to the Central or Midland district of England, the difference between the most forward and the most backward season of the seven years comes out as 25 days. Of course with any particular kind of plant the range is considerably greater. For instance, the average date for the blackthorn in 1894 was March 28, and in 1891 May 2; while the hawthorn was first in blossom in 1893 on April 23; and in 1891 it did not flower till May 29—giving a range for these two shrubs of respectively 35 and 36 days.

Observations of the flowering of cultivated plants, provided the same specimens be noted each year, are of interest as showing the comparative forwardness or lateness of the seasons in any particular locality. But the varieties of these are now so numerous, that such plants are of little service for comparing the relative progress of vegetation in different parts of the country, the conditions under which they are grown varying so much more than with our native species.

Concluding Remarks.

The foregoing is but a hasty and imperfect review of an extremely wide subject. I trust, however, I have at least made one thing perfectly clear, and that is the powerful influence, both for good and ill, that all important weather changes have upon cultivated plants in this country. Most farmers and gardeners understand this in a way, but few realise to its full extent the power and waywardness of the master they have to work with and serve under. Our native plants are naturally hardy, and it is only occasionally that weather influences seriously affect them. But then it must be borne in mind that they only grow, as a rule, in places and in soils where their modest requirements are fully met. It is when we try to grow plants in a variety of soils and situations for which they are not by nature adapted, that we begin to find out what a number of enemies of all kinds they have to contend against. Indeed, it is a species of warfare in which the conditions are sometimes favourable and sometimes unfavourable, and in the latter case it often becomes a long struggle for existence against adverse circumstances. But the contest is not so unequal as would at first appear, for most of the crops and plants we grow appear to be endowed with true British endurance, and seem never to know when they are beaten. I of course refer to the wonderful recuperative powers which most plants possess, and which enable them to recover to a great extent even from seemingly irreparable injuries.

There are a few lessons which all tillers of the soil, whether in garden or on farm, may learn from a consideration of this question of the effect of weather upon vegetation, viz.—

1. To grow such crops, and such varieties of each, as can be cultivated with the greatest success in the soil at their disposal, and in the particular climate in which their lot may be cast.

2. To follow the best modes of culture for each crop. For it will be

found that crops on ill-cultivated land are, as a rule, far more at the mercy of seasons than those on land which is highly cultivated. Besides which, it has been shown at Rothamsted that a full crop, instead of impoverishing the soil, leaves it, as a rule, in better heart than a poor one.

3. It is also advisable not to place too many eggs in one basket, but rather to grow a variety of crops, knowing, for instance, as we do, that a season favourable for grass and roots is often unfavourable to corn, and *vice versa*.

4. Another very important lesson taught by the fickleness of our climate is, that each farm and garden operation should, as far as practicable, be begun directly a spell of weather favourable for it sets in, for we never know how soon such a propitious period may come to an end, or how long the adverse conditions which may succeed it will continue.

I cannot conclude this address without some reference to the long and splendid series of experiments that have been carried on by Sir John Lawes and Sir Henry Gilbert at Rothamsted in Hertfordshire unremittingly for more than half a century, and to which I have had occasion so frequently to refer. My only regret is that time would not allow of my studying, as they deserve, the numerous admirable reports of these experiments, which they kindly placed at my disposal. Speaking as a horticulturist and meteorologist, the one weak point at the Rothamsted farm appears to me to be the want of a sufficiently complete meteorological station in connection with it. A station after the pattern of the Society's second order stations, with the addition of a sunshine recorder, a self-registering anemometer, and several earth thermometers, is all that would be necessary. For it is only by the careful examination of meteorological observations, in conjunction with records of the extent and character of the growth of our leading farm and garden crops, week by week, that the close connection which exists between weather changes and their influence on such crops can be clearly traced.

It is, however, not only at Rothamsted that such meteorological stations are required in connection with experimental plots of land bearing crops of different kinds, but also in other parts of the British Isles, as well as at many experimental farms in other parts of the world.

My hearty thanks are due to all those who have so kindly assisted me by furnishing materials for the preparation of this address, and especially to Sir Henry Gilbert, F.R.S., Mr. J. J. Willis, and Mr. T. Wilson of Harpenden.

REPORT OF THE COUNCIL

FOR THE YEAR 1897.

IN presenting their Report the Council have again to congratulate the Society on an increase in the number of Fellows and the satisfactory condition of the finances.

The Council feel that the Fellows will deeply regret the loss the Society has sustained by the death of the Hon. Ralph Abercromby, so well and deservedly known for his labours in connection with Meteorology. The great interest which he took in the Society is shown by the legacy referred to below.

Committees.—The Council have been materially assisted by several Committees during the year, which were constituted as follows:—

EDITING COMMITTEE.—Messrs. Bayard and Inwards, Vice-Admiral Maclear, and Mr. Scott.

GENERAL PURPOSES COMMITTEE.—The President, Secretaries, Foreign Secretary, Treasurer, Messrs. Ellis, Inwards, and Williams.

HOUSE ACCOMMODATION COMMITTEE.—The President, Secretaries, Messrs. Inwards, Latham, Scott, and Williams.

WIND FORCE COMMITTEE.—The President, Secretaries, Messrs. Chatterton, Curtis, Dines, C. Harding, Munro, Scott, and Captain Wilson-Barker.

Exhibition.—The fact that the year under review was the sixtieth year of Her Majesty's reign, induced the Council to hold an exhibition illustrative of "Meteorological Instruments in use in 1837 and in 1897." By the kind permission of the President and Council of the Institution of Civil Engineers, this was held in the Library of the Institution from March 16 to 19, both inclusive. The exhibits of instruments representing those in use in 1837 were twenty-nine, and those of modern date one hundred and sixteen, while numerous diagrams and photographs were also shown. On March 17, at the desire of the Council, Mr. G. J. Symons, F.R.S., delivered an address on the subject of the Exhibition before a large audience of the Fellows of the Society and their friends.

Address to H.M. the Queen.—The Council presented a loyal and dutiful address to Her Majesty the Queen, on the completion of the sixtieth year of her reign, and they received from the Home Secretary a letter stating that "Her Majesty was pleased to receive the same very graciously."

Stations.—Observations have been accepted from the following new stations:—Bognor, Sussex; Brundall, Norfolk; Isfield, Sussex; Shaftesbury, Dorset; and Rumney, Monmouthshire. The observations have been discontinued at Addiscombe, Brampford Speke, Somerleyton, and Stowell. The Council have been trying to get a station established on the top of the Tower at Blackpool, Lancashire, but, owing to the absence of any sign of local support, and to the fire which took place there while the matter was under consideration, the organisation of this station has been indefinitely postponed. Copies of detailed monthly returns for certain stations, and annual summaries of results for others, have been supplied, as usual, to the Meteorological Office.

Inspection of Stations.—All the stations south of latitude 52° N. and

east of longitude 2° W., as well as such new stations as could be conveniently visited, have been inspected, and found on the whole to be in a satisfactory condition. Mr. Marriott's Report is given in Appendix II. p. 90.

Legacy from Mr. Abercromby.—The Council in November received a letter from the solicitors to the executors of the late Hon. Ralph Abercromby stating that under his settlement the Society was entitled to a legacy of £100, subject to legacy duty. The amount of the same, viz. £90, has since been paid to the Society. The Society has also received under the bequest a considerable collection of meteorological instruments, books, pamphlets, and MSS., a list of which is given in Appendix IV. p. 103.

Research Fund.—The Council regret that no donations to this fund have been received during the year.

Library.—Considerable additions, by presentation and purchase, have been made to the Library, as well as to the collection of photographs and lantern slides. The Council have also received from Mr. G. J. Symons a fire-proof deed box; from Mr. W. Ellis a mercurial thermometer, believed to be a hundred years old; and from Mr. H. Perigal two maximum and two minimum thermometers made in 1854. Of these presentations and purchases a list will be found in Appendices V. and VI. pp. 107, 108.

Lantern Slides.—Arrangements have now been made by which Fellows can borrow lantern slides.

Quarterly Journal.—This publication has contained, amongst other papers of interest, the address on thermometer exposure, for the determination of shade temperature, by the President; a paper by Mr. R. H. Curtis on the relation between the velocity of the wind and the numbers of the Beaufort Scale; and a paper by Messrs. Scott and Gaster on the maximum and minimum temperatures observed in the British Isles in the 25-year period, 1871-95.

Investigations.—(1) A valuable report by Mr. R. H. Curtis on the comparative results obtained from the Campbell-Stokes and from the Jordan Sunshine Recorders was read at the meeting on November 17, and will appear in the *Quarterly Journal* in due course. (2) The wind force experiments on board the Nautical Training College, H.M.S. *Worcester*, are being continued.

Meteorological Record.—This publication has been brought up to June 1897, and is now in the seventeenth year of its existence.

Hints to Observers.—As the third edition of this necessary publication had been exhausted, the Council early in the year issued a fourth edition with some improvements, which they trust will be useful.

Phenological Report.—This interesting and instructive annual report was, as usual, prepared by Mr. Mawley, and read at the February meeting. An improvement has this year been introduced by the employment of average dates for the different plants derived from the previous six years' observations.

Sanitary Congress.—At the request of the Council Messrs. Dickson and Baldwin Latham attended as delegates from the Society the Sanitary Congress held at Leeds in September.

National Physical Laboratory.—The Council having been invited to submit evidence to the Committee appointed by Government to consider

the desirability of establishing this Department, requested Messrs. Ellis and Scott to give evidence on behalf of the Society.

Offices.—The Council have not yet received any intimation from H.M.'s Office of Works as to the date at which they will be required to vacate their rooms. They have, however, requested Mr. Penfold, the eminent surveyor, to advise them in the matter, and hope that, when the time comes to vacate their present extremely suitable offices, the Government will deal generously with the Society.

Meetings.—As the rooms of the Institution of Civil Engineers were not available for the meetings in May and June, the Society, by the kind permission of the Council of the Royal Astronomical Society, held its meetings in those months at the rooms of that Society at Burlington House. These meetings were held in the afternoon as an experiment, and this change seems to have been much appreciated by Fellows residing in the country, many who had been usually unable to attend the evening meetings being present.

Fellows.—The changes in the number of Fellows are exhibited in the following table, which shows an increase of seven during the year:—

Fellows.	Annual.	Life.	Honorary.	Total.
1896, December 31	418	141	17	576
Since elected . . .	+32	+4	...	36
Since compounded .	− 2	+2	...	0
Deceased	− 11	− 2	− 1	− 14
Retired	− 10	...	...	− 10
Struck off	− 1	...	...	− 1
Lapsed	− 2	...	...	− 4
1897, December 31	422	145	16	583

Deaths.—The Council have to announce with much regret the deaths of one Honorary Member and of thirteen Fellows. The names are:—

Antoine d'Abbadie (Honorary Member)	elected	May	18, 1892.
Hon. Ralph Abercromby	„	Feb.	17, 1869.
Gustav Valentine Alsing, Assoc.M.Inst.C.E.	„	Dec.	18, 1889.
John Thomas Barber, F.R.A.S.	„	March	16, 1882.
Louis Pascal Casella, F.R.A.S., F.R.G.S.	„	Jan.	15, 1862.
Rev. John Edward Cross, M.A., F.R.A.S., F.G.S.	„	June	18, 1862.
William Coulthard Falls, M.A., M.B., M.R.C.S.	„	April	19, 1893.
Rev. Edward Whitmose Ford	„	March	16, 1881.
Leonard Willson Gatward	„	May	16, 1888.
James Heywood, F.R.S., F.G.S., F.S.A.	„	June	18, 1862.
Francis John Pastorelli	„	June	20, 1866.
Rev. George Thomas Ryves, M.A.	„	Dec.	16, 1874.
Walter Thomas, Assoc.M.Inst.C.E.	„	Jan.	16, 1895.
Joseph Warren Zambra	„	Nov.	27, 1855.

APPENDIX

STATEMENT OF RECEIPTS AND EXPENDITURE

RECEIPTS.

Balance from 1896			£133 5 2
Subscriptions for 1897	£688 1 0		
Do. for former years	42 0 0		
Do. paid in advance	38 0 0		
Life Compositions	126 0 0		
Entrance Fees	32 0 0		
		926 1 0	
Meteorological Office—Copies of Returns	£110 10 5		
Do. Grant towards Inspection Expenses	25 0 0		
		135 10 5	
Dividends on Stock (including £40 : 18 : 3 from the New Premises Fund)		122 4 6	
Sale of Publications, &c.		58 3 4	
Legacy by the Hon. Ralph Abercromby (£100, less Legacy Duty)		90 0 0	
		£1465 4 5	

I.

FOR THE YEAR ENDING DECEMBER 31, 1897.

EXPENDITURE.

Journal, &c.—					
Printing Nos. 101 to 104	£153	11	9		
Illustrations	40	16	4		
Authors' Copies	16	7	6		
Meteorological Record, Nos. 63 to 65	40	15	6		
Registrar-General's Reports	6	6	0		
				£257	17 1
Printing, &c.—					
General Printing	£20	3	6		
Hints to Observers, 4th Edition	36	7	1		
Stationery	13	11	4		
Books and Book-Binding	11	14	3		
				81	16 2
Office Expenses—					
Salaries	£420	2	0		
Rent and Housekeeper (3 quarters)	150	0	0		
Repairs, Coals, &c.	13	11	0		
Postage	51	7	3		
Petty Expenses	11	0	3		
Refreshments at Meetings	12	17	2		
Exhibition of Instruments	20	7	7		
				679	5 3
Observations—					
Inspection of Stations	£52	13	8		
Observers	9	2	0		
Instruments	2	14	3		
				64	9 11
Stock—					
Purchase of £50, L. & N.-W. R. Consolidated Stock, at 200½				101	1 0
				£1184	9 5
Balance—					
At Bank of England	£278	0	9		
In hands of the Assistant-Secretary	2	14	3		
				280	15 0
				£1465	4 5

Examined and found correct,

FRED$^{C.}$ GASTER,
M. JACKSON, } *Auditors.*

January 11, 1898.

APPENDIX

ASSETS AND LIABILITIES

LIABILITIES.

To Subscriptions paid in advance	£38 0 0	
,, Meteorological Record, No. 66	10 2 6	
,, Rent for quarter ending December 25, 1897 . .	50 0 0	
		£98 2 6
,, Excess of Assets over Liabilities[1]		3436 17 4
		£3534 19 1

[1] This excess is exclusive of the value of the Library and Stock of Publications.

WM. MARRIOTT, *Assistant-Secretary.*

NEW PREMISES FUND

Amount paid to the Society's Funds towards the increased rent of the New Premises	£40 18 3

RESEARCH FUND

Amount invested in the purchase of £2 : 17 : 3, 2¾ per cent Consols .	£3 4

I.—Continued.

ON JANUARY 1, 1898.

ASSETS.

By Investment in G.C.R. 4½ per cent Debenture Stock, £800 at 160	£1280	0	0			
,, Investment in N.S.W. 4 per cent Inscribed Stock, £654 : 18s. at 121¼	794	1	4			
,, Investment in L. & N.-W. R. Consolidated Stock, £250 at 204½	511	5	0			
,, Investment in 2½ per cent Annuities, £231 : 11 : 9 at 106¼	246	1	3			
				£2831	7	7
,, Subscriptions unpaid, estimated at	£50	0	0			
,, Entrance Fees unpaid	8	0	0			
,, Interest due on Stock	51	18	4			
				109	18	4
,, Furniture, Fittings, &c.	£197	4	5			
,, Instruments	115	14	6			
				312	18	11
,, Cash at Bank of England	£278	0	9			
,, Cash in hands of the Assistant-Secretary	2	14	3			
				280	15	0
				£3534	19	10

Examined,

FRED$^{C.}$ GASTER,
M. JACKSON, } *Auditors.*

January 11, 1898.

DECEMBER 31, 1897.

Interest received on investment £40 18 3

Note.—The Society holds on account of this Fund £1209 : 4 : 10 South Australian 4 per cent Inscribed Stock.

Examined,

FRED$^{C.}$ GASTER,
M. JACKSON, } *Auditors.*

January 11, 1898.

DECEMBER 31, 1897.

Interest received on investment £3 4 7

Note.—The Society holds on account of this Fund £121 : 4 : 7, 2¾ per cent Consols.

Examined,

FRED$^{C.}$ GASTER,
M. JACKSON, } *Auditors.*

January 11, 1898.

APPENDIX II.

INSPECTION OF STATIONS, 1897.

I have inspected all the stations south of 52° N. lat., and east of 2° W. long., together with several new stations and a few others which could be conveniently visited.

The stations were on the whole in a satisfactory condition, the observers taking great interest in the work.

It is always necessary to urge that careful attention should be given to the working of the wet bulb thermometer.

Comparatively few changes have taken place in the zeros of the thermometers, the most being in the minima.

During the inspection I tested four grass minimum thermometers made by Mr. Hicks, with the scale let in at the back of the tube. These I found to be all reading too low by several degrees, varying from 3°·0 to 5°·1. As these were all new thermometers, the change must have been very rapid. I have communicated with Mr. Hicks upon the subject, but he is not able at present to give any explanation of the strange behaviour of this particular pattern of thermometer.

At some of the stations there is a difficulty in maintaining a good exposure for the sunshine recorder, owing to the growth of trees. What was a very satisfactory exposure when the instrument was first put up, has now, in some cases, become unsatisfactory, as trees in the neighbourhood have since grown up and intercept the early morning or late evening sunshine. At two or three stations this has to some extent been overcome by moving the recorder from one position to another according to the season of the year. But at other stations this is not possible. It may soon become necessary to consider whether it is desirable to publish the records from such stations, where an absolutely clear horizon is not available.

I am looking forward with much interest to Mr. Curtis's report on the comparison of the Campbell-Stokes and the Jordan sunshine recorders, and trust that it will not only clear up some of the apparent discrepancies between the two patterns, but also remove some of the difficulties which occur in obtaining satisfactory and comparable measurements of the records.

WM. MARRIOTT.

October 19, 1897.

NOTES ON THE STATIONS.

ADDINGTON, *September* 23.—There was no change in the thermometers. The observer seemed to under-estimate the amount of cloud. Some time ago the observer suddenly commenced reading the wrong end of the index of the minimum thermometer, and continued to do so till July last.

ASPLEY GUISE, *September* 22.—The earth thermometers had been moved since the last inspection to another position near the ther-

mometer screen. On comparing the thermometers it was found that the 6-inch earth thermometer had gone up 0°·5.

BEDDINGTON, *September* 23.—There was no change in the instruments at this station.

BELMONT, *September* 2.—I recommended a rearrangement of the thermometers in the screen. The rain gauge is of the Glaisher pattern with a curved pipe. I straightened the pipe in order that the rain might fall direct into the can below.

BENNINGTON, *September* 20.—This station was in good order. I recommended a rearrangement of the thermometers in the screen.

BERKHAMSTED, *September* 17.—This station was in good order. I recommended that the legs of the thermometer screen should be strengthened. On comparing the thermometers it was found that the grass minimum, with a mica scale let in at the back of the tube, had gone down 5°·1.

BEXHILL, *July* 15.—The thermometers are on a lawn in a very open situation on high ground overlooking Bexhill, and about a mile from the sea. The rain gauge is some distance off and at a lower level. The Jordan sunshine recorder is mounted on a post above a hedge. I found that the sunshine papers had been measured before being fixed. I recommended that for the future the papers should be fixed before being measured. The grass minimum thermometer had 8° of spirit up the tube. On October 22 I again visited Bexhill and put up a Campbell-Stokes sunshine recorder, which is mounted on a post about 10 feet high. The Jordan recorder is mounted on another post about 3 feet south and 1 foot lower. The other instruments were all in good order.

BOGNOR, *July* 20.—The instruments are in a railed-off enclosure in a large open field in front of the pier. The thermometers required some slight rearrangement in the screen. The Jordan sunshine recorder (cheap pattern) is mounted on the tower of the church and has a good exposure. The instrument, however, required adjusting.

BOURNEMOUTH, *August* 26.—The sunshine recorder is still in the cemetery, but the trees evidently cut off the evening sun. The recorder, which is of the universal pattern, was not in proper adjustment, the scale being set for lat. 54½° instead of 50¾°. The ball was not in the centre of the frame, nor was the pedestal quite level. Mr. Primavesi, the observer, who is also an optician, promised to put the recorder in proper adjustment. The thermometer screen and rain gauge have been removed from the cemetery to the ground attached to the water tower and pumping station, in the public gardens near the pier. The exposure is by no means as satisfactory as that in the cemetery. The committee of the corporation have not, however, accorded the Society permission to use the results.

BRIGHTON, *July* 19.—The mercury in the maximum thermometer has a tendency to run up the tube. I recommended that the thermometer should be raised a little before being read. The screen required cleaning and painting. It is desirable that another rain gauge should be placed in a more favourable situation. On comparing the ther-

mometers it was found that the minimum had gone down 0°·2. Owing to building operations at the Town Hall, the sunshine recorder had been removed to the Sanatorium on the Downs, where there is a very good exposure.

BRUNDALL, *September* 15.—This station is six miles east of Norwich. The instruments are placed in a railed-off enclosure in a paddock a short distance from the railway. The ground slopes to the south, and overlooks the river Yare. I recommended that the legs of the screen should be strengthened and that back plates with hole and slot should be put on the back of the maximum and minimum thermometers.

CHELMSFORD, *July* 8.—Dr. Thresh had moved from the Limes to Spegula, about 250 yards south, at the end of November 1896. The instruments are in a paddock within a railed-off enclosure. I recommended a rearrangement of the railing, as the rain gauge was not very well placed. The screen required painting. On comparing the thermometers it was found the minimum had gone down 0°·2.

CRANLEIGH, *July* 20.—The muslin on the wet bulb was dry, as the thread was not conducting properly. The screen required strengthening. I recommended that the maximum and minimum be rearranged in the screen.

CULLOMPTON, *August* 30.—There was no change in the thermometers. The sunshine recorder was not in good adjustment, the ball not being in the centre of the frame. The frame had been unscrewed at the back, and wedges put in, which had thrown it on one side. I took these wedges out, and readjusted the instrument.

EASTBOURNE, *July* 17.—The rain gauge had been moved to the west of the thermometer screen a few months previously. The grass minimum had 1° of spirit up the tube. On comparing the thermometers it was found that the minimum had gone up 0°·3. The sunshine recorder, which is on the tower of the Grand Hotel, was in good order.

FOLKESTONE, *July* 13.—The maximum sets very stiffly, and has an air-speck in the column. I suggested that the thermometer should be mounted somewhat inclined. The muslin on the wet bulb had been allowed to become dry. I recommended that a cap should be put over the water receptacle. It would be an advantage if the railed-off enclosure were much larger.

GATTON, *September* 25.—There was no change in the thermometers. I recommended a rearrangement of the thermometers in the screen. The sunshine recorder has to be moved according to the season of the year, on account of the trees in the neighbourhood.

GUERNSEY, *August* 13.—The tube of the minimum is liable to slip, as it is not a permanent fixture. The tube of the maximum had also slipped about a degree. I recommended a rearrangement of the thermometers on the screen. The Jordan sunshine recorder evidently does not get the late evening sun in summer, as the side of the roof makes an angle of 8°. I recommended that the recorder should be raised about 3 feet.

GWERNYFED PARK, *September* 2.—I gave the observer instruction in the reading and manipulation of the instruments, and in estimating the amount of cloud, as, owing to the change of gardener, he had not received any previous instruction. The screen required strengthening and painting. The minimum had about 1°·5 of spirit up the tube.

HALSTEAD, *September* 10.—There was no change in the zeros of the thermometers. I recommended a rearrangement of the thermometers in the screen, which was carried out while I was present.

HARESTOCK, *August* 23.—Everything at this station was clean and in good order. The 70-foot earth thermometer has been satisfactorily established, and is in good working order. Colonel Knight has an extensive set of instruments, comprising more than 30 thermometers, as well as barometer, wind vane, 2 anemometers, 2 sunshine recorders, 2 rain gauges, and 2 evaporation tanks.

IPSWICH, *September* 13.—The instruments are placed on a grass plot belonging to the Museum. This site is by no means satisfactory, as it is much too confined, the thermometer screen being practically in the shade all day, except in the morning. I urged that the instruments should be moved to a more open situation, and recommended that they should be placed on the lawn in front of the mansion in Coventry Park.

ISFIELD, *July* 16.—This station is about five miles north-north-east of Lewes. The instruments are placed in a large circular railed-off enclosure in a field. The exposure is very good. I recommended a rearrangement of the thermometers on the screen. On comparing the thermometers it was found that the dry and wet had gone up 0°·3, that the maximum had gone up 0°·2, that the earth thermometer had gone up 0°·4, and that the grass minimum had gone down 4°·4. This last instrument had the scale let in at the back of the tube. The thermometer was returned to the maker, who sent another one of the same pattern in its place. The two measuring glasses for the rain gauges did not agree together, one of them having an error of ·02 in. in some parts of the scale. This necessitated a revision of the rainfall records. I visited this station again on September 21, and found all the thermometers correct, except the new grass minimum which had gone down 3°·0. It is very strange that both the grass minimum thermometers of this particular pattern had gone down so much in such a short time.

LISS, *August* 20.—The sunshine recorder does not get the full sunshine, as the trees on the north-east to south-east cut off the morning sun. The instrument would be much better exposed on the roof of the house, if raised sufficiently to be clear of the chimneys. The recorder was tilted up with a stone, as it was set to the latitude of 41° instead of 51°. The ball was not in the centre of the frame.

LOWESTOFT, *September* 14.—The tube of the 1-foot earth thermometer had slipped down very considerably since the last inspection, and was about 7° too low. Mr. Miller took the instrument to a shop in the town, and had it partly taken to pieces. I then raised the tube to its proper position, and packed it up with pieces of cork. On re-testing

the thermometer in water it appeared to read correctly with the standard.

MANNINGTREE, *September* 14.—The instruments are placed in an old burying-ground which has been levelled and grassed over. They are only a short distance from the river. The screen was rather low, the bulbs of the thermometers being only 3 ft. 6 ins. above ground. I recommended a rearrangement of the thermometers in the screen.

MARGATE, *July* 13.—The minimum had 0°·5 of spirit at the top of the tube. The sunshine recorder is of the universal pattern. The ball was not in the centre of the frame, having slipped down. I readjusted this by placing a piece of wood under the ball to keep it in position.

OLD STREET, E.C., *September* 16.—There was no change in the thermometers. The screen required cleaning. As the trees have grown up very much I recommended that they be cut back as much as possible, so as to leave the rain gauge quite clear.

PENZANCE, *August* 30.—I recommended that the instruments should be moved if possible to a more open site, as the present one is surrounded by trees. The screen required painting. The two sunshine recorders are mounted on the top of the Market House. The ball of the Campbell-Stokes recorder required a little adjustment.

PORTSMOUTH, *August* 20.—On comparing the thermometers it was found that both the earth thermometers had gone up 0°·2. The grass minimum had 2°·5 of spirit up the tube. The Jordan sunshine recorder is placed on the top of the thermometer screen, but does not get all the sunshine, especially in the evening. I recommended that the instrument should be placed in a better position, and also gave instructions as to the measurement of the trace.

REGENT'S PARK, *September* 16.—The screen required to be cleaned and painted. Three of the earth thermometers had portions of mercury up the tube. The 6-inch, 1-foot, and 4-foot are not graduated on the stem, but are long thermometers enclosed in iron tubes. I had these thermometers taken out of the soil, and then united the column of mercury. I also tested these long thermometers by placing them in the lake. The 6-inch and 1-foot were fairly correct, but the 4-foot, when standing upright, read about 0°·4 too low.

ROUSDON, *August* 27.—As the index of the minimum was liable to be shaken down by the wind, I had the thermometer mounted quite horizontally. On comparing the thermometers I found that the grass minimum had gone down 4°·2, after allowing for 0°·9 of spirit up the tube. This thermometer had the scale let in at the back of the tube. I recommended that the sunshine recorder should be raised considerably, as the house and trees from west-south-west to west-north-west make an angle of more than 6°.

RUMNEY (WITLA COURT), *September* 1.—This station is on the Newport Road, four miles north-east of Cardiff. I found that the instruments were not in position, so I selected a site in a field with a good exposure. I explained to the gardener how the instruments were to be mounted and the observations made.

SHAFTESBURY, *August* 25.—The town of Shaftesbury is 700 feet above sea-level, and is built on the top of a hill. The instruments are placed in the garden in front of the Hospital, which overlooks a steep declivity on the south-east. The wet bulb was not working properly. I recommended a rearrangement of the thermometers in the screen.

SHEERNESS, *July* 12.—Owing to a breakdown of the pumping arrangements no observations had been taken since July 1896. After some conversation with Mr. Copland, he agreed to resume the climatological observations and also the sunshine records. The screen required painting. I recommended that the trees round the rain gauge should be cut back as much as possible.

SWARRATON, *August* 24.—There was no change in the thermometers. The screen required painting. I requested that more attention should be given to the wet bulb in frost.

TENTERDEN, *July* 14.—The Jordan sunshine recorder is placed in the garden on the east side of the road, for the morning previous to 9 a.m., it is then removed to the garden at the back of the house. A large willow tree intercepted the sunshine in the early morning in summer. I recommended that the recorder should be placed in another part of the west garden in summer. This was subsequently carried into effect with satisfactory results.

THURLOW, *September* 10.—There was no change in the thermometers. I recommended that a cap should be put over the water receptacle. The trees have grown up round the thermometer screen, so it will probably be necessary soon to remove the instruments to a more open situation.

TUNBRIDGE WELLS, *September* 21.—On comparing the thermometers it was found that the dry and wet had gone up 0°·2. The screen required painting. I rearranged the thermometers in the screen. The ball of the Campbell-Stokes sunshine recorder was not in the centre of the frame. This I readjusted.

VENTNOR, *August* 21.—The wet bulb was not working properly, as the conducting thread was too thin. On comparing the thermometers it was found that the minimum had gone down 0°·3. The sunshine recorder is mounted on a concrete pedestal on a hillock close to the cliff. The exposure is good, except on the west. The hill from the west through north makes an angle of 5°.

WALLINGTON, *September* 23.—I recommended a rearrangement of the thermometers in the screen, and that the screen should be strengthened. On comparing the thermometers it was found that the minimum had gone down 0°·2 and the grass minimum 0°·4. The Jordan sunshine recorder is mounted on a board projecting from a chimney. The exposure is very good.

WEYMOUTH, *August* 26.—The index of the maximum was too long, so I requested the observer to have it shortened by immersing the thermometer in a mixture of salt and ice. The muslin on the wet bulb required to be changed more frequently. The sunshine recorder is mounted in a pan on the top of an iron tripod on the shelter at the end

of the pier. It is levelled with corks, which are liable to shift. I recommended that it should be firmly fixed. Mr. Eyles informs me that when the big guns in the fort are fired the whole pier jumps as though it were coming bodily out of the water, and the glass ball invariably leaves its pedestal. Fortunately this does not often happen.

WINTERSLOW (ROCHE COURT), *August* 24.—This station is eight miles east of Salisbury, nearly on the borders of Wilts and Hants, and is on the chalk downs 468 feet above sea-level. The instruments are in a railed-off enclosure in the park. The ground slopes to the south and south-east. The thermometers required rearranging in the screen. The sunshine recorder required adjusting.

WOOLACOMBE, *August* 31.—There was no change in the thermometers. The sunshine recorder is mounted on a brick pier in the best situation possible. The hills to the north of east and to the south of east make an angle of 7°. There is a valley due east. On the west all is open to the sea.

WORTHING, *July* 19.—The minimum had 1°·1 of spirit up the tube. The screws for holding the maximum and minimum required to be tightened to prevent the thermometers vibrating in the wind. I recommended that some branches be lopped off two trees near the rain gauge.

APPENDIX III.

OBITUARY NOTICES.

ANTOINE THOMPSON D'ABBADIE was born in Dublin, of French parents, in the year 1810. His family returned to France in 1818, where he was educated. He early devoted himself to the study of geography, geodesy, and terrestrial magnetism. In August 1836 he determined the magnetic inclination at Paris. In 1837 he went to Olinda, in Brazil, where he studied the diurnal variations of the needle between the magnetic and terrestrial equators. The details of these observations were not published till 1873, when they appeared in a memoir, entitled *Observations relatives à la Physique du Globe faites au Brésil et en Éthiopie.*

From 1837 to 1839 he was engaged with his brother, Michael Arnauld d'Abbadie, in making his first exploration of Ethiopia, and a second voyage was undertaken in the period 1839 to 1849. It is certain, however, that for some time in 1839 he was in Paris, as he there made a second determination of the magnetic inclination, to compare with that made three years previously. The results of these twelve years' geographical and geodetical work were published in 1873, under the title *Géodésie d'Éthiopie, ou Triangulation d'une Partie de la Haute-Éthiopie, exécutée selon des Méthodes Nouvelles.*

Though M. d'Abbadie gave much attention to linguistic work, he applied himself to astronomical pursuits with some eagerness. In 1857 he visited Norway, with the view of observing the total solar eclipse of that year. The point to which he directed his attention was the

examination of the light of the solar prominences for the detection of polarisation. With the view of still further satisfying himself on this point, he took advantage of the eclipse of 1860 to go to Spain, where, accompanied by M. Petit of the Toulouse Observatory, he made some further observations at Briviesca. Observing with a quartz plate and double-image prism of small angle of separation, no trace of polarisation was detected. Later, in 1882, and notwithstanding his advanced age, M. d'Abbadie took charge of one of the French stations selected for the observation of the transit of Venus. The position occupied was at Port au Prince, in Saint Domingo, a station well adapted for observing the effects of both retarded ingress and accelerated egress. The observations were successful.

M. d'Abbadie belonged to the Institut de France for forty years, and for nearly twenty years he had been a member of the Bureau des Longitudes. Simple in his manner and kind-hearted in his nature, he was ever ready to give assistance to those who appealed to him for advice, and his loss is deeply regretted by all who were favoured with his acquaintance. He died in Paris, March 19, 1897, at the age of 87 years, signalising his love for astronomy by bequeathing an estate in the Pyrenees, yielding 40,000 francs a year, to the Académie des Sciences, on condition of its publishing within fifty years a general catalogue of stars.

He was elected an Honorary Member of this Society on May 18, 1892.

Hon. RALPH ABERCROMBY was born in 1842, and was the youngest son of the third Lord Abercromby. His mother was a daughter of Lord Medwyn, a Lord of Session in Edinburgh. Several of his immediate relatives had been eminently distinguished. His great-grandfather, Sir Ralph Abercromby, who died in 1801, in the moment of victory, at the Battle of Alexandria, had served his country with brilliant distinction in the West Indies (Trinidad) and at the Helder. As soon as the news of Sir Ralph's death reached England, and in commemoration of his services, a barony was conferred upon his widow, with remainder to his sons.

Of these sons the second became Sir John. He was in the service of the East India Company, and took the Island of Mauritius in 1810. Another was Speaker of the House of Commons in 1835, and was created Lord Dunfermline.

Ralph was never robust, even as a boy. He went to Harrow, and soon was obliged, owing to delicacy, to leave the school. He had, however, shown signs of great promise by taking a double remove after his first term.

In June 1860 he was gazetted to the 60th Rifles, and four years later obtained his lieutenancy and joined the Fourth Battalion at Quebec. The War of Secession was then at its height. He obtained leave and visited the scene of action. He took with him letters to General Grant, and was well received, but he did not happen to be present at any of the great battles.

At the beginning of 1866 he entered the Staff College, having passed in without "cramming," but his health soon broke down there.

Two visits to Kreuznach produced no benefit, and in 1869, to his great regret, he felt himself obliged to give up his commission.

In later years he twice was sent on a voyage round the world, in hopes of restoration to health; and it was in the beginning of 1890, at the commencement of a third voyage to the Pacific, that he was taken ill at Sydney—an illness which terminated fatally, June 21, 1897. He passed away quietly in his sleep.

Mr. Abercromby had, from a very early period, paid much attention to observational meteorology. In his *Seas and Skies in many Latitudes* observations are recorded which he must have made during his military service in Canada. In April 1864 he wrote an essay on "A Scientific Explanation of the Popular Weather Prognostics of Scotland," in competition for the prize offered by the Marquis of Tweeddale through the Scottish Meteorological Society. His name will live longest in connection with the new classification of clouds which he, in conjunction with Prof. Hildebrandsson, of Upsala, proposed, and which was adopted by a majority of votes at the International Meteorological Conference of Paris in September 1896.

The following is a list of his published books, and of the papers which he communicated to various societies and periodicals:—

"On the Heat and Damp which accompany Cyclones" (*Quart. Jour. Roy. Met. Soc.* 1875).
"On certain small Oscillations of the Barometer" (*Quart. Jour. Roy. Met. Soc.* 1875).
"On the Barometric Fluctuations in Squalls and Thunderstorms" (*Quart. Jour. Roy. Met. Soc.* 1875).
"An Improvement in Aneroid Barometers" (*Quart. Jour. Roy. Met. Soc.* 1877).
"Visibility" (*Quart. Jour. Roy. Met. Soc.* 1877).
"On the General Character and Principal Sources of Variation in the Weather at any part of a Cyclone or Anticyclone" (*Quart. Jour. Roy. Met. Soc.* 1878).
"On the Application of Harmonic Analysis to the Reduction of Meteorological Observations, and on the General Methods of Meteorology" (*Quart. Jour. Roy. Met. Soc.* 1878).
"On a method of sometimes determining the Amount of the Diurnal Variation of the Barometer on any particular day" (*Quart. Jour. Roy. Met. Soc.* 1878).
"The Tay Bridge Storm" (*Nature*, 1880).
"On the Diurnal Variation of Wind and Weather in their relation to Isobaric Lines" (*Quart. Jour. Roy. Met. Soc.* 1882).
"The Spectroscope and Weather Forecasting" (*Nature*, 1882).
"On certain Types of British Weather" (*Quart. Jour. Roy. Met. Soc.* 1883).
"Popular Weather Prognostics"—Joint paper with W. Marriott (*Quart. Jour. Roy. Met. Soc.* 1883).
"On the Reduction of Wind Records" (*Quart. Jour. Roy. Met. Soc.* 1883).
"'Festooned' or 'Pocky' Clouds (Mammato-cumulus)" (*Nature*, 1883).
"Principles of Forecasting by means of Weather Charts" (Published by the Authority of the Meteorological Council, 1885).
"On the Identity of Cloud Forms all over the World; and on the general principles by which their indications must be read" (*Quart. Jour. Roy. Met. Soc.* 1887).
"On the Cloud to which the name 'Roll Cumulus' has been applied" (*Quart. Jour. Roy. Met. Soc.* 1887).
"Suggestions for an International Nomenclature of Clouds" (*Quart. Jour. Roy. Met. Soc.* 1887).
"The Peculiar Sunrise-shadows of Adam's Peak in Ceylon" (*Philosophical Magazine*, 1887).
"Weather: A Popular Exposition of the Nature of Weather Changes" (*International Science Series*, 1887).
"Modern Developments of Cloud Knowledge" (*Jour. Scott. Met. Soc.* 1887).
"On the Relation between Tropical and Extra-tropical Cyclones" (*Proceedings Roy. Soc.* 1887).
"Electrical and Meteorological Observations on the Peak of Teneriffe" (*Quart. Jour. Roy. Met. Soc.* 1888).

"Seas and Skies in many Latitudes" (1888).
"Observations on the Height, Length, and Velocity of Ocean Waves" (*Philosophical Magazine*, 1888).
"On Meldrum's Rules for handling Ships in the Southern Indian Ocean" (*Proceedings Roy. Soc.* 1888).
"Cloud-land in Folklore and in Science" (*Folklore Journal*, 1888).
"First Report of the Thunderstorm Committee; On the Photographs of Lightning Flashes received by the Royal Meteorological Society" (*Quart. Jour. Roy. Met. Soc.* 1888).
"Observations on Cloud Movements near the Equator; and on the General Character of the Weather in the 'Doldrums'" (*Quart. Jour. Roy. Met. Soc.* 1888).
"Instructions for observing Clouds on Land and Sea" (1888).
"On Meldrum's Rules for handling Ships in the Hurricanes of the Southern Indian Ocean" (*Jour. Scott. Met. Soc.* 1889).
"Observations on the Motion of Dust, as illustrative of the Circulation of the Atmosphere and of the Development of certain Cloud Forms" (*Quart. Jour. Roy. Met. Soc.* 1890).
"Signs in the Sky" (*Good Words*, 1890).

From his sick bed in Sydney Mr. Abercromby showed his great interest in the advancement of the science by making grants of money for the production of essays on meteorological subjects. Three of these have been published: "On Moving Anticyclones in the Southern Hemisphere," "On Southerly Bursters," and "On Types of Australian Weather."

Mr. Abercromby retained to the very last the power of making and keeping friends. This was in great measure due to his loyal and affectionate nature, which neither distance nor illness could impair. Those who were with him during his last suffering months bear witness to the patience and gentleness, which were as conspicuous under the trials of severe pain as they had been when he was in full possession of his faculties.

His lot was indeed a hard one. He had first to bear the heavy disappointment of enforced resignation of a profession which he loved, and in which his prospects seemed so brilliant, and then he had to sustain the strain of more than twenty years of impaired and gradually failing health. He leaves behind him the memory of a warm unselfish friend, cut off in a distant land, far from his kith and kin.

Mr. Abercromby was elected a Fellow of this Society on February 16, 1869. He served on the Council for several years, and was a Vice-President in 1884.

JOHN THOMAS BARBER was born at Derby on June 23, 1825, and died at Norwood on March 25, 1897. From 1864 till 1883 he lived at Sponden, in Derbyshire, and from 1883 till his death at Hoperay, Aston-on-Clun, Salop.

Mr. Barber, who was a Fellow of the Royal Astronomical Society, took great interest in astronomical and meteorological observations.

He was elected a Fellow of this Society on March 16, 1882.

LOUIS PASCAL CASELLA was born in Edinburgh in the year 1809. His father was a member of an old Italian family belonging to Como and Milan, and his mother was the daughter of General Ramsey of Edinburgh. After being educated at Edinburgh, he removed to London about 1835. Shortly afterwards he joined Mr. Tagliabue as a philosophical instrument maker, whose daughter he subsequently married, and

succeeded to the business, which, by his perseverance, intelligence, and courteous and genial manner, he brought to its present state of high eminence.

In the construction of meteorological, surveying, and engineering instruments Mr. Casella attained a very high excellence; and many important improvements and inventions in scientific instruments were made by him. He brought out several meteorological instruments, and his name is connected with many others. The most important of the instruments which he introduced were the Maximum Thermometer on Phillips' principle: the Miller-Casella Deep-Sea Thermometer; the Mercurial Minimum Thermometer; the Clinical Thermometer; the Air Meter, etc.

Mr. Casella's kindliness of disposition was well known, but far more noteworthy was his benevolence to those who were in need.

He died on April 23, 1897, at his residence at Highgate, in the eighty-ninth year of his age.

Mr. Casella was elected a Member of the old Meteorological Society of London on June 8, 1841, and became a Fellow of this Society on January 15, 1862. He was also a Fellow of the Royal Astronomical and the Royal Geographical Societies.

Rev. JOHN EDWARD CROSS was born at Red Scar, Preston, Lancashire, on April 10, 1821. He was educated at Rugby and Christ Church, Oxford, and was ordained in 1846 to a curacy in Bolton, where he remained till 1849, when he became curate and then vicar of Appleby, in Lincolnshire. He became Prebendary of Leicester St. Margaret's in 1880, and in 1882 Rural Dean of Manlake. He resigned the living of Appleby in 1891. His health failed soon after, and he died, after a long and painful illness, at Scarborough on February 28, 1897.

Canon Cross was interested in astronomy and meteorology. He built an observatory at Appleby, and made numerous observations with his transit and equatorial telescopes.

He was a Fellow of the Royal Astronomical Society, and also of the Geological Society.

He was elected a Fellow of this Society on June 18, 1862.

WILLIAM COULTHARD FALLS was born in London in 1853, and was the son of the late Dr. W. S. Falls of Bournemouth, who settled there, when the future health resort was a fishing village, and did much to promote its rising prosperity. Young Falls was educated at Winchester and Merton College, Oxford, where he graduated M.A., M.B., in 1881, after studying medicine at St. George's Hospital. He entered into general practice in Brompton, becoming partner of Dr. Fyfe, of Montpelier Square, and was following his profession at the time of his death from apoplexy on November 26, 1897.

Dr. Falls, like his father, was fond of yachting and travel. He visited the shores of the Mediterranean several times, and twice crossed the Atlantic to the Pacific coast. He was much interested in meteorology, and was elected a Fellow of this Society on April 19, 1893.

JAMES HEYWOOD was the fifth son of Mr. Nathaniel Heywood, banker, of Manchester, and was born on May 28, 1810. He was educated at Trinity College, Cambridge, where he was a Senior Optime in 1833; but he did not graduate B.A. till 1857, when the obligatory subscription to the Articles of the Church of England was abolished.

Mr. Heywood was a supporter of the Free Library movement, and for years found the funds for the support of a Free Library at Notting Hill.

He died on October 18, 1897.

Mr. Heywood was elected a Fellow of the Royal Society as long ago as 1839; he was also a Fellow of the Geological Society, and published several works on geological subjects.

He was elected a Fellow of this Society on June 18, 1862.

FRANCIS JOHN PASTORELLI was born in London on October 6, 1822. After an early education he was sent to Italy to complete his studies, as his father wished him to follow his business as a manufacturer of scientific instruments. Returning to London, he was trained under his father to acquire a thorough knowledge of the trade; and in after-years he was recognised as one of the most accurate manufacturers of the day.

In the Exhibition of 1862 Mr. Pastorelli was awarded a medal for novel improvements and superior excellence of workmanship. He patented a surveying level, and was the sole manufacturer of Metford's traversing theodolite.

Mr. Pastorelli communicated two papers to this Society, viz. (1) "On the method adopted for dividing Alcohol Minimum Thermometers" (*Proceedings*, vol. iv. p. 264). (2) "Errors of Low Range Thermometers" (*Quarterly Journal*, vol. ii. p. 407).

Mr. Pastorelli was upright and honourable in both business and private life, and was greatly esteemed for his kindly and generous nature. He died on March 17, 1897.

He was elected a Fellow of this Society on June 20, 1866.

Rev. GEORGE THOMAS RYVES was educated at Winchester and at Brasenose College, Oxford. He took his B.A. degree in 1857 and M.A. in 1860. He was ordained deacon by the Bishop of Lichfield in 1859 and priest in 1860. He was curate of Sutterton, Lincolnshire, 1870-71, and vicar of Buildwas, Salop, 1871-74. In 1874 he became vicar of Tean, Staffordshire, which living he held until his death.

Mr. Ryves was a man of broad and liberal principles, and always ready to co-operate with his brother ministers of religion in all Christian and philanthropic work. As a pastor, he was beloved for his kindness of heart, especially in ministering to those in sickness and need.

Mr. Ryves was an ardent meteorological observer, and a frequent contributor to the columns of the local press on the subject of the weather.

He died on January 30, 1897, aged 63.

He was elected a Fellow of this Society on December 16, 1874.

JOSEPH WARREN ZAMBRA was born at Saffron Walden, December 6, 1822. His father was an Italian, of the same business in which

the son afterwards was to gain such a reputation, but his mother was an Englishwoman. Having served his apprenticeship to the instrumental glass blowing he was for a short time taken into partnership by his employer, Mr. Tagliabue. Mr. Henry Negretti, after commencing his career in a similar way, had just started business on his own account. Very soon, however, Mr. Negretti and Mr. Zambra entered into partnership as philosophical instrument makers, and founded the business which has become of world-wide reputation.

The Universal Exhibition of 1851 brought this firm prominently before the public for the novelty and perfection of their scientific instruments. From that time, by the patronage of such men as Mr. Glaisher, etc., they rapidly developed into a firm of first-class reputation. Most of their inventions relating to meteorological instruments were brought before this Society; as, however, these were always described as the joint productions of Messrs. Negretti and Zambra, it is not possible to divide their merit. The following are some of their inventions:—

Maximum Thermometer, invented in 1851.

Mercurial Minimum Thermometer with steel indices, invented in 1853.

Double Bulb Six's Thermometer, invented in 1857, enabling Six's instrument to be used for taking temperature observations of the deepest seas unaffected by the pressure of the water.

Gun Barometer, constructed in 1860 for use in the Royal Navy.

Pocket Aneroid, a reduction of the ordinary sized aneroid to meet the requirements of Admiral FitzRoy, afterwards still further reduced to the "watch" size.

Mercurial Minimum Thermometer with platinum stop, invented in 1861.

New Travelling and Standard Barometer.

Maximum Thermometer for use at sea, in deep wells, etc., invented in 1874.

Recording Turn-over Thermometer, invented in 1874, for deep sea observations and self-registering observations in connection with clock work.

Deep Sea Thermometer with Reversing Float, invented in 1878, which has also been applied for recording purposes in connection with clock work.

New Form of Six's Thermometer, invented 1880.

Their attention, however, was not confined to this particular branch of science, for they have, in their time, supplied almost every form of philosophical instrument, and have been also engaged in various forms of commercial agency.

Personally Mr. Zambra was a man who never sought a public reputation. Of strict and upright habits, he loved his home, and was little known outside his own circle of friends; but to those who knew him intimately he displayed an exceedingly kind and considerate disposition. He, like the late Mr. Negretti, was a genuine man in every sense, and his loss will be long felt.

He died after only two days' illness on December 23, 1897.

He was elected a Fellow of this Society on November 27, 1855.

APPENDIX IV.

BEQUEST BY THE LATE HON. RALPH ABERCROMBY.

INSTRUMENTS.

Thomson's Portable Electrometer.
Fineman's Nephoscope.
Two Aneroids (4½ ins.).
Three Aneroids (2 ins.).
Aneroid, with Compass combined (1¼ ins.).
Travelling Thermometer.
Black-bulb Maximum Thermometer *in vacuo*.
Metallic Thermometer (1 in.).
Clock cylinder for Richard's recording instruments.
Two Rainband Spectroscopes.
Chronograph (3 seconds).
Arithmometer.
Pantograph.
Binocular Glasses.
Negatives of Clouds.
Lantern Slides of Clouds.
Photographic Utensils.

BOOKS AND PAMPHLETS.

ABBE, C.—A Plea for Terrestrial Physics.—Observations on the Total Eclipse of the Sun of 1869.

ABERCROMBY, R.—Cloudland in Folklore and in Science.—Modern Developments of Cloud Knowledge.—Observations on the Height, Length, and Velocity of Ocean Waves. —On the Relation between Tropical and Extra-tropical Cyclones.

ADELAIDE, METEOROLOGICAL SOCIETY OF AUSTRALASIA.—List of Members, 1887. —Minutes of Proceedings, 1886-87, vol. ii.

ANEROID BAROMETER, how to buy and how to use it.

ARATUS.—The Skies and Weather Forecasts of Aratus.

ASSMANN, R.—Eine neue Methode zur Ermittelung der wahren Lufttemperatur.

AUGUSTIN, F.—O poměru skvrn slunečních k. teplotě Pozemské.

BEALL, G.—Handbook to Beall's Compass Devioscope.

BEBBER, J. VAN.—Anleitung zur Aufstellung von Wetterprognosen auf Grundlage der Zeitungs-Wetterkarten und Isobaren-Telegramme.

BEDFORD, F .G. D.—The Sailor's Hand-book.—The Sailor's Pocket-book. 3rd ed.

BEN NEVIS, METEOROLOGICAL OBSERVATORY.—An account of its foundation and work.

BERLIN, HYDROGRAPHISCHES AMT DER ADMIRALITÄT.—Segel-Handbuch für die Nordsee. Erstes Heft.

BERLIN, KÖN.-PREUSSISCHES METEOROLOGISCHES INSTITUT.—Beobachtungen über die Gewitter und Gewitterstürme des Jahres 1886.—Instruction für die Regenstationen. —Instruction für die Gewitter-Beobachter.

BEZOLD, W. VON.—Experimentaluntersuchungen über rotirende Flüssigkeiten.—Über eine nahezu 26-tägige Periodicität der Gewitterscheinungen.—Ueber zündende Blitze im kön. Bayern während des Zeitraumes 1833 bis 1882.—Zur Thermodynamik der Atmosphäre, parts i.-iii.

BILLINGHURST, G. E.—El abastecimiento de agua portable del Puerto de Iquique.—Estudio sobre la geografia de Tarapacá.

BLAKE, C. C.—The Future, vol. i. No. 5.

BLANFORD, H. F.—A Practical Guide to the Climates and Weather of India, Ceylon, and Burmah.—Rainfall and Climate of India.

BÖRNSTEIN, R.—Die Gewitter vom 13-17 Juli 1884 in Deutschland.

BRIDET, M.—Étude sur les ouragans de l'hémisphère Austral. 3rd ed.

BRITISH NEW GUINEA, GOVERNMENT SECRETARY'S OFFICE.—Report on British New Guinea from Sept. 4, 1888, to June 30, 1889.

BRÜCKNER, E.—Das Klima der Eiszeit.—Die Schwankungen des Wasserstandes im Kaspischen Meer, dem Schwarzen Meer und der Ostsee in ihrer Beziehung zur Witterung. —In wie weit ist das heutige Klima konstant?—Resultate der meteorologischen Beobachtungen der deutschen Polar-stationem 1882-83.

BUCH, L. VON.—On the Climate of the Canary Islands.

BUCHAN, A.—The Specialities of the Weather of 1872.

CALCUTTA METEOROLOGICAL DEPARTMENT OF THE GOVERNMENT OF INDIA.—Bay of Bengal Weather Charts, May to Oct. 1884, and Feb. 14-24, and Mar. 1-17, 1886.—Memorandum to accompany charts of temperature and rainfall of India, by H. F. Blandford.—Meteorological and Rainfall Table of the Province of Bengal, May to Oct. 1884.

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CLARIDGE, J.—The shepherd of Banbury's rules to judge of the changes of the weather. 2nd ed.

CLAYTON, H. H.—Loomis' contributions to meteorology, reviewed by H. H. Clayton.

COOPER, A. J.—How to forecast the Weather Months in advance.—The Unequal Distribution of Heat over the Earth's Surface.

CORNU, M. A.—Étude des Bandes Telluriques α, B et A du spectre solaire.—Notice sur les raies telluriques du spectre solaire.—Sur l'absorption atmosphérique des radiations ultra-violettes—Sur les coefficients d'absorption de l'atmosphère pour les rayons ultra violets et l'influence probable de l'ozone sur la variation de ces coefficients.—Sur les raies telluriques qu'on observe dans le spectre solaire au voisinage des raies D.

CORTÉS, D. J.—El non plus ultra del lunario y pronostico perpetuo.

CRUICKSHANK, A.—On the horizontal visual penetrability of the atmosphere.

CURTIS, G. E.—An account of the progress in Meteorology for the year 1889.—The hot winds of the plains.

DARWIN, C.—A Naturalist's Voyage.

DAVIS, W. M.—Mountain Meteorology.

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DELAUNEY.—La prévision du temps. Annuaire pour 1897.

DENHAM, M.A.—A collection of Proverbs and Popular Sayings relating to the Seasons.

DENZA, F.—Sulla variazione della temperatura secondo l' altezza nelle regioni di Montagna.

DICKSON, H. N.—The Hygrometry of Ben Nevis.

EKHOLM, N.—Ueber die tägliche Variation des Luftdruckes während des nordischen Winters.

EKHOLM, N., and HAGSTRÖM, K. L.—Mesures des hauteurs et des mouvements des nuages.—Molnens höjd i Upsala under sommaren.

ELSON, S. R.—The Sailor's East Indian Sky Interpreter and Weather Book.

ELSTER, J., and GEITEL, H.—Ueber eine Methode, die elektrische Natur der atmosphärischen Niederschlage zu bestimmen.

FERRARI, C.—Beiträge zur Gewitterkunde.

FINEMAN, C. G.—Spegelnefoskopet och dess användning vid molnobservationer.

FLAMMARION, C.—L'Atmosphère, Météorologie populaire.

FORSTÉN, R.—Ueber der Zusammenhang der Cirrusbewegung mit der Fortpflanzung der Depressionen.

FORSTER, T.—Researches about Atmospheric Phænomena.

GEIKIE, A.—Elementary Lessons in Physical Geography.

GREELY, A. W.—American Weather.

GUILBERT, G.—Études météorologiques de la prévision des nuages et des Tempêtes.

GUILLEMIN, A.—Les météores électriques et optiques.

GUTHRIE, F.—Outline of experiments for illustrating elementary instruction in sound, light, heat, magnetism and electricity.

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HANN, J.—Der Scirocco der Südalpen.—Die False Point Cyclone von 22 Sept. 1885.—Einige Bemerkungen zur Lehre von den allgemeinen atmosphärischen Strömungen.—Resultate des ersten Jahrganges der meteorologischen Beobachtungen auf dem Sonnblick.—Ueber den Föhn und sein Auftreten in den Ostalpen.

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HINRICHS, G.—Re-election or Reorganisation.

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VON HORN, G. F.—Die Kunst des Wetterprophezeins oder: Die Wetterzeichen und Bauernregeln nebst einem Anhange: Die Wetter-Prophezeiungen des hundertjährigen Kalenders.

IOWA, WEATHER SERVICE.—Reports, 1885 and 1887.—The Seasons in Iowa.

JACKSON, R.—The Principal Winds and Currents of the Globe.

KIESSLING, J.—Die Bewegung des Krakatau-Rauches im September 1883.

KLEIN, H. J.—Allgemeine Witterungskunde nach dem gegenwärtigen Standpunkte der meteorologischen Wissenschaft.

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MANILA, OBSERVATORIO METEOROLÓGICO.—Observaciones Magnéticas, 1888.—Observaciones verificadas, Jan. to Mar. 1883.

MARCHI, L. DE.—Meteorologia. Sulla dinamica dei temporali.

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MASCART, E.—La météorologie appliquée à la prévision du temps.

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MAURY, M. F.—The Physical Geography of the Sea. New ed.

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MILNE, D.—Notices of Earthquake Shocks felt in Great Britain, and especially in Scotland.

MOHN, H.—Grundzüge der Meteorologie. 3rd ed.—Les phénomènes de l'atmosphère, traité illustré de météorologie.

MÖLLER, M.—Ueber Gestalt und Bewegung von Wasserwellen in stehenden und fliessenden Gewässern mit Berücksichtigung der Einwirkungen des Windes.—Untersuchung über die Lufttemperatur und Luftbewegung in einer Böe.—Wetter-Berather. Anleitung zum Verständniss und zur Vorherbestimmung der Witterung.

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NEUMAYER, G.—Auf die Mondbewegung gegründete Sturmwarnungen.

NICHOL, J. P.—A Cyclopædia of the Physical Sciences. 2nd ed.

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PUNTA ARENAS (PATAGONIA), OFICINA METEOROLÓJICA.—Observaciones meteorolójicas hechas en 1887.

RIO DE JANEIRO, MINISTÈRE DES AFFAIRES DE LA MARINE.—Règlement du Bureau Central de Météorologie approuvé par le Décret n. 9. 916 du 4 Avril 1888.

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ROSSER, W. H.—Short Notes and Sailing Directions for the China Sea.—Stellar Navigation.—The Law of Storms considered Practically.

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ROWELL, G. A.—Electric Meteorology.

RUETE, D.—Die Taifune der Chinesischen Meere.

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SMOCK, J. C.—Climatology of New Jersey.

SMYTH, W. H.—The Mediterranean.

SPRUNG, A.—Continuirliche Registrirung des Robinson'schen Schalenkreuzes.—Die tägliche Periode der Richtung des Windes.—Lehrbuch der Meteorologie.—Ueber die Theorien des allgemeinen Windsystems der Erde.—Untersuchung eines Aneroid Barographen der Gebr. Richard en Paris.

SYDNEY, OBSERVATORY.—Observations of the Transit of Venus, Dec. 9, 1874.

TAYLOR, J.—The Complete Weather Guide.

TEISSERENC DE BORT, L.—Sur la prévision du temps.

THOMSON, Sir W., and TAIT, P. G.—Elements of Natural Philosophy, Part I.

TOKIO, GEOGRAPHICAL BUREAU.—Report of an Expedition to Mount Fuji, 1887.

TOKIO, IMPERIAL METEOROLOGICAL OBSERVATORY.—Tri-daily Weather Maps, Jan. 1885 to March 1891.

TURIN, SOCIETÀ METEOROLOGICA ITALIANA.—Istruzioni per le osservazioni della forma delle nuvole.

UPTON, W.—The Storm of March 11-14, 1888.

VETTIN, F.—Die Einwirkung der barometrischen Minima und Maxima auf die Richtung des Windes und Wolkenzuges.—Die Einwirkung der barometrischen Minima und Maxima auf die Richtung des Wolkenzuges im Sommer- und Winterhalbjahr.—Die Luftströmungen über Berlin.—Die Luftströmungen über Berlin in den vier Jahreszeiten.—Erwiderung auf die Kritik meiner Messungen der Wolkenhöhe durch Herrn Jesse.—Experimentelle Darstellung von Luftbewegungen unter dem Einflusse von Temperatur-Unterschieden und Rotations-Impulsen.—Hohenbestimmung der Wolken aus der Zeit der Beleuchtung von Sonnenauf- oder nach Sonnenuntergang.—Projicirte Geschwindigkeit der Wolken und deren Bestimmung.—Ueber die Volumina der in die barometrischen Minima und Maxima hinein und aus denselben herausströmenden Luft.

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WASHINGTON SIGNAL OFFICE.—Bulletin of International Meteorology, 1875-79, 1881-84, and 1886-88.—Charts showing the average monthly cloudiness in the United States.—Charts showing the isobars, isotherms, and winds in the United States for each month from Jan. 1871 to Dec. 1873.—Charts showing the "probability of rainy days."—Charts showing the rainfall in the United States for each month from Jan. 1870 to Dec. 1873.—Daily International Charts, July to Dec. 1884, and Oct. 1886 to Dec. 1887.—General subject indexes to the Monthly Weather Reviews, and Annual Reports of the Chief Signal Officer to 1887.—Instructions to Tornado Reporters.—Memoranda on the work accomplished by the Signal Service.—

Normal temperature charts by decades for the United States and the Dominion of Canada.

WHIPPLE, G. M.—Observations of Atmospheric Electricity at the Kew Observatory during 1880.

WICHMANN, H.—Geographischer Monatsbericht.

WILD, H.—On the Determination of the true Air Temperature.

WOEIKOF, A.—Die Klimate der Erde.

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ZEGERS, L. L.—Descripcion de una nueva pila electrica.—Noticia acerca de la Cordillera de los Andes.—Transito de Venus por el Sol.

ZI-KA-WEI, OBSERVATOIRE MÉTÉOROLOGIQUE ET MAGNÉTIQUE.—Les Typhoons de 1882, Part I.

APPENDIX V.

BOOKS, ETC., PURCHASED DURING THE YEAR 1897.

BOOKS AND PAMPHLETS.

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CHAMBERS, G. F.—The Story of the Weather. 8° (1897).

HELLMANN, G.—Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus:

No. 7, Evangelista Torricelli; Esperienza dell' Argento Vivo. Accademia del Cimento; Istrumenti per conoscer l' Alterazioni dell' Aria. 4° (1897).

No. 8. E. Halley, A. von Humboldt, E. Loomis, U. J. Le Verrier, E. Renou: Meteorologische Karten, 1688, 1817, 1846, 1863, 1864. 4° (1897).

No. 9. Henry Gellibrand: A Discourse Mathematical on the Variation of the Magneticall Needle. London, 1635. 4° (1897).

MITTERMAIER, K.—Maderia und seine Bedeutung als Heilungsort. Nach mehrjährigen Beobachtungen für Aerzte geschildert. 8° (1855).

SCOTT, R. H.—Elementäre Meteorologie, von R. H. Scott; übersetzt von W. von Freeden. 8° (1844).

SYMONS' MONTHLY METEOROLOGICAL MAGAZINE.—Index, vols. i.-xxx., 1866-95. 8° (1897).

VINIZIANO, E. S.—Dissertazione sopra le aurore boreali. 4° (1738).

YEAR-BOOK OF THE SCIENTIFIC AND LEARNED SOCIETIES of Great Britain and Ireland, 1897. 8° (1897).

LANTERN SLIDES.

BECKLEY'S Anemometer.
CROSLEY'S Registering Rain-Gauge.
DE LUC'S Whalebone Hygrometer.
DINES' Pressure Tube Anemometer.
FLIGHT OF KITES AND METEOROGRAPH at Blue Hill Observatory, Feb. 1897.
KATER'S Hygrometer.
KITE METEOROGRAPH RECORD, Blue Hill Observatory, Oct. 8, 1896.
OSLER'S Anemometer.
OSLER'S Anemometer at the Royal Observatory, Greenwich.
PEDIMENT BAROMETER with float.
RUTHERFORD'S Maximum and Minimum Thermometers.
SAUSSURE'S Hair Hygrometer.
SIX'S Thermometer.
SOMERSET HOUSE, Strand.
WHEWELL'S Anemometer.
WHEWELL'S Anemometer in use at the Royal Observatory, Greenwich, 1843-62.

APPENDIX VI.

DONATIONS RECEIVED DURING THE YEAR 1897.

Books and Pamphlets.

Presented by Societies, Institutions, etc.

Adelaide Observatory.—Observations made at the Adelaide Observatory and other places in South Australia and the Northern Territory, 1894.—Rainfall in South Australia and the Northern Territory, 1894.

Aix-la-Chapelle, meteorologische Station.—Ergebnisse der meteorologischen Beobachtungen, 1896.

Allahabad, Meteorological Office.—Annual Statement of Rainfall in the North-West Provinces and Oudh, 1896.

Bangalore, Central Observatory.—Results of Observations taken at the Bangalore, Mysore, Hassan, and Chitaldroog Observatories, 1895.

Barbados, Colonial Secretary's Office.—Returns of Rainfall in Barbados, 1897.

Batavia, Koninklijke Natuurkundige Vereeniging in Ned. Indie.—Alphabetische Register op Deel i.-l. van het Natuurkundig Tijdschrift voor Nederlandsche Indie.

Batavia, Magnetical and Meteorological Observatory.—Observations, 1895-96.—Rainfall in the East Indian Archipelago, 1895-96.—Wind and weather, currents, tides, and tidal streams of the East Indian Archipelago.

Berlin, Deutsche meteorologische Gesellschaft.—Meteorologische Zeitschrift, Dec. 1896 to Nov. 1897.

Berlin, Gesellschaft für Erdkunde.—Verhandlungen, Band xxiii. No. 9 to Band xxiv. No. 9.—Zeitschrift, Band xxxi. No. 5 to Band xxxii. No. 4.

Berlin, Königlich-Preussisches meteorologisches Institut.—Bericht über die Thätigkeit des Königlich-Preussischen meteorologischen Instituts in Jahre 1896.—Ergebnisse der Beobachtungen an den Stationen II. und III., Ordnung 1893, Heft 3; 1896, Heft 2; 1897, Heft 1.—Ergebnisse der Gewitter-Beobachtungen, 1892, 1893, and 1894.—Ergebnisse der magnetischen Beobachtungen in Potsdam, 1894, Heft 2; 1895, Heft 2.—Ergebnisse der meteorologischen Beobachtungen in Potsdam, 1895.—Ergebnisse der Niederschlags-Beobachtungen 1894.

Bermuda, General Register Office.—Report of the Registrar-General, 1896.

Bidston, Liverpool Observatory.—Report of the Director of the Observatory, 1896.

Bremen, meteorologische Station.—Ergebnisse der meteorologischen Beobachtungen, 1896.

Brisbane, Chief Weather Bureau.—Meteorological Instructions.—Observations taken at Meteorological Stations in Queensland, Jan. to June 1896.—Summaries of Rainfall 1896.—Weather Charts of Australasia, Aug. 2 to Sept. 16, 1897.

Brisbane, General Register Office.—Annual Report on the Vital Statistics of Queensland, 1896.—Report on Vital Statistics, Oct. 1896 to Sept. 1897.

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British New Guinea, Government Secretary's Office.—Annual Report on British New Guinea, 1895-96.

Brussels, Académie Royale de Belgique.—Annuaire, 1896-97.—Bulletin, 3me série, tome xxx.-xxxiii.—Règlements et documents concernant les trois classes.

Brussels, Observatoire Royale de Belgique.—Annales: Observations météorologiques d'Uccle, Aug. 1894 to Mar. 1895.—Annuaire, 1897.—Bulletin météorologique, Dec. 1896 to Nov. 1897.

Bucharest, Institut météorologique de Roumanie.—Annales, tome xi. 1895.—Buletinul Observatiunilor Meteorologice din Romania, 1896.

Budapest, Königl.-Ung. Central-Anstalt für Meteorologie und Erdmagnetismus.—Jahrbuch, 1894.

Cairo, Société Khédiviale de Géographie.—Bulletin, 4me série, Nos. 10-12.

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MAWLEY, E.—Meteorological Station, Berkhamsted, July 1896 (3 slides).—Meteorological Station, Royal Botanic Gardens, Regent's Park, Sept. 1884.—Thermometer Screens, Royal Observatory, Greenwich.—Thermometer Screens:—Stevenson, Martin, Lawson, James, Pastorelli, Griffith, Stow, Kew, French, German, and Stevenson shaded (12 slides).

RUSSELL, H. C.—Lightning.

PHOTOGRAPHS.

CURTIS, H. P.—Waterspout, Vineyard Sound, U.S., Aug. 19, 1896 (4 photos).

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KING, Major H.—Royal Meteorological Society's Second-order Station, Isfield, Sussex (5 photos).

MAWLEY, E.—Thermometer Screens at Berkhamsted: German and Stevenson shaded screens (3 photos).

ROTCH, A. L.—Keel Kite.—Steam winch for Keel Kite.

TAYLOR, Capt. E. R.—Meteorological Station at Ardgillan (3 photos).

INSTRUMENTS, ETC.

ELLIS, W.—Thermometer.

PERIGAL, H.—Two Maximum and Two Minimum Thermometers.

SYMONS, G. J.—Fire-Proof Box.

APPENDIX VII.

REPORTS OF OBSERVATORIES, ETC.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. Sir R. Strachey, R.E., G.C.S.I., F.R.S., Chairman of Council; Robert H. Scott, M.A., F.R.S., Secretary; Nav. Lieut. C. W. Baillie, F.R.A.S., Marine Superintendent.

MARINE METEOROLOGY.—*Current Charts for all Oceans.*—These have now been all published. For the Atlantic Ocean only six charts have been published, inasmuch as the variations in the currents are neither so rapid nor so well defined as in the Indian Ocean, for which twelve monthly charts were given. In the Atlantic only one chart can be consulted for the months of December, January, and February; other charts refer to two months, and November alone is represented by a special chart. The Pacific charts have also appeared. Here the material is very scanty, and only four charts have been given, for January, April, July, and October respectively.

The charts for the South Indian Ocean (Cape of Good Hope to New Zealand) have not yet appeared, but may be looked for at an early date.

South Atlantic Ocean.—The discussion of the material for this region, extending from the coast of Africa to the meridian of 100° W. in the Pacific, makes steady progress.

Weather Telegraphy.—No material change has been made in the work of this department. It is intended to increase the number of records of sunshine given in the *Weekly Weather Report* in view of the constantly increasing interest taken by the public in this special observation.

British Rain, 1866-90.—This publication appeared in the autumn; the stations represented are in all 492, viz.: in England and Wales, 287; Scotland, 151; and Ireland, 54.

Part I. gives the monthly and annual rainfall at stations in the British Islands for every year from 1881-90; for the Lustra 1881-85 and 1886-90; and for the longest period in complete Lustra for which the returns for the selected stations have been published by the Meteorological Office. Part II. contains the monthly and annual rainfall at stations included in Part I., for years from 1866-80, which were not published in 1883, with means for the several Lustra. Part III. contains an abstract of mean monthly and annual rainfall for the ten years 1881-90, at the stations included in Part I., arranged according to counties, with references to the tables which supply the several values. There is also an appendix to Part III., giving references to the returns of rainfall for 1866-80, published in 1883, for stations which are not included in Part I. of the present publication. The work is illustrated by three maps showing the main watersheds and the catchment basins of the principal rivers.

Land Meteorology of the British Isles.—The volume of *Hourly Mean Readings for the Five Observatories* for 1894 has appeared, and that for 1895 is in hand. It is purposed in addition to publish for the two observatories of Valencia and Kew the detailed hourly readings, the printing of which has been discontinued since 1886.

The volume of *Results of Observations for Stations of the Second Order* has appeared for 1894, and that for 1895 is in progress. It is in contemplation to publish returns from a number of foreign stations from which records are in the Office. These will supply information from several districts in more or less distant regions.—*February* 14, 1898.

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, C.B., M.A., F.R.S., Astronomer-Royal.

The site for the Magnetic Pavilion has now been approved by H.M. Office of Works; a station having been selected in the Park 300 to 400 yards east of the Observatory, with ample space for mounting the standard meteorological instruments, thus ensuring better conditions of exposure. The space at present available in the Magnetic Observatory grounds is far too small, and the further extension of the Physical Observatory buildings now in progress will interfere seriously with the proper circulation of air. The sunshine instrument is maintained in its new position on the roof of the Octagon Room. The new glass ball to this instrument has been used throughout the year with satisfactory results: the old ball having been in use on the old Campbell recorder by the side of the Campbell-Stokes instrument for comparison.

The result of the comparison is as follows :—

RECORDED SUNSHINE, 1897.

	New ball.	Old ball.
	hrs.	hrs.
January	19·8	10·8
February	34·1	24·2
March	123·4	101·7
April	144·7	124·8
May	251·6	220·6
June	178·3	145·8
July	252·7	213·7
August	219·8	183·9
September	114·5	90·8
October	111·7	85·9
November	41·7	29·7
December	50·3	36·5
Year	1542·6	1268·4

The record for the year by the old ball is thus only 82 per cent of that by the new ball.

On November 12, Mr. Marriott, of the Royal Meteorological Society, and Mr. R. H. Curtis, of the Meteorological Office, inspected the sunshine instruments. After a careful examination of the defective ball with a powerful lens, Mr. Curtis concluded that its opacity was entirely upon the surface, having probably been caused by the action of the sulphuretted hydrogen in the atmosphere, and that this might be removed by repolishing. It has been decided, however, to retain the ball in its normal condition.

The old Whewell anemometer was on loan to the Royal Meteorological Society for their annual Exhibition of Instruments, from March 16 to 19.

The principal characteristics of the weather in the year 1897 were as follows : The temperature of the air ranged from 90°·2 on June 24 to 23°·3 on December 24, and the annual mean was 50°·3, being 0°·9 above the average. The sunniest month was July, with a total amount of 253 hours, and a percentage of 51. There were only 11 sunless days in December, with a total amount of sunshine for the month of 50 hours. The rainfall for the year amounted to 22·13 ins., being 2·22 ins. below the average for the preceding 56 years. In July the rainfall was only 0·73 in., being less than any July rainfall since 1885, whilst in October the fall was only 0·48 in., being the smallest October rainfall on record.—*March* 5, 1898.

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.S.E., Astronomer-Royal for Scotland.

The regular daily meteorological register commenced at the new Royal Observatory, Blackford Hill, Edinburgh, on January 1, 1896, has been carried on throughout the past year without interruption. In addition to the instruments used in 1896, which are fully described in the report for that year, a pair of black bulb thermometers, exposed *in vacuo*, were placed in position on January 1, 1897, the minimum on the grass near the 8-inch rain-gauge and the maximum on brackets attached to the south side of the louvred thermometer box. The readings of these thermometers have been included in the monthly returns sent to the Scottish Meteorological Society.

These returns contain the daily readings at 9 a.m. and 9 p.m. of the standard barometer and of the various thermometers, with estimates of the direction and force of the wind and of the amount of cloud. The monthly means have been printed in the Reports of the Registrar-General for Scotland.

The hemispherical-cup anemometer and direction vane have been in operation throughout the year, and a continuous record of both the velocity and direction has been secured on the Casella recording instrument. Though storms have been frequent, the speed of the wind has only on a few occasions exceeded about 55 miles an hour. On the morning of February 25, the rate averaged 57 miles an hour from 5 to 8 a.m. On November 12, it averaged 60 miles from 6.30 to 9 a.m. and on December 26, 450 miles were recorded in the seven hours from 1 to 8 p.m., showing an average velocity of 64 miles per hour. Perhaps even more remarkable than these high velocities was the long-continued calm, extending from January 9 at 8 p.m. to January 12 at the same hour. During this period of three days 280 miles of wind passed the anemometer, giving a rate of only 4 miles an hour. The wind was East for the first 24 hours, afterwards veering from West-south-west to South-east. Other calm periods were experienced on February 12-13, when only 50 miles were recorded in 25 consecutive hours, and on August 1-2 when an average rate of only $1\frac{1}{2}$ miles per hour continued for about 22 hours.

Weekly readings of the rock thermometers at Calton Hill have, as in former years, been made by the staff of the Royal Observatory.—*January* 22, 1898.

KEW OBSERVATORY, RICHMOND, SURREY.—Charles Chree, Sc.D., F.R.S., Superintendent.

The several self-recording instruments for the continuous registration of atmospheric pressure, temperature of air and wet-bulb, wind (direction and velocity), bright sunshine, and rain, have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records duly registered. The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

Electrograph.—The auxiliary battery of 60 chloride of silver cells used with this instrument was received back from the makers on January 11. Before restarting the instrument, the Clifton quadrant electrometer was taken entirely to pieces, all parts thoroughly cleaned and dried, and new sulphuric acid put in the inner jar. The battery was tested, each row of cells being examined and the voltage determined.

The electrograph was started on January 19, and has been in constant operation since, with the exception of one or two short stoppages due to freezing of the water jet, or other accidental causes. Owing presumably to the changes introduced last year, there has been a great improvement in the behaviour of the apparatus. There are still, however, one or two directions in which further improvement is desirable.

On September 29, one-third of the cells in the battery were taken off, to make a corresponding contraction in the scale values, which was expedient in view of the high potentials usually recorded during the winter months. Notwithstanding this, several hours' record have been lost owing to the trace being off the sheet. It is difficult at present to see how such loss can be avoided without either duplicating part at least of the apparatus, so as to get two curves, one showing ordinary and the other extraordinary potentials (positive and negative), or else by risking possible loss of negative trace by shifting the position, on the sheet, of the zero line.

The scale value was determined by direct comparison with the portable electrometer, White, No. 53, on January 19, May 4, and on September 29, before and after the change above referred to. The comparisons showed that up to the date of the change the scale value had remained practically constant.

Atmospheric Electricity.—The comparisons of the potential, at the point where the jet from the water-dropper breaks up, and at a fixed station on the observatory lawn, referred to in last year's Report, have been continued, and the observations have been taken nearly every month. A comparison of these observations with the corresponding results from the electrograms encourages the belief that there has been no progressive change of insulation in the electrograph, such as was met with prior to the late alterations and improvements.

Advantage was taken of the occurrence of some very thick fogs in November, to carry out six sets of observations of the potential at various heights from the ground to 70 feet above.

Fog and Mist.—The observations of a series of distant objects, referred to in previous Reports, have been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour.

Aneroid Barometers.—The experiments referred to last year have been continued, and a considerable number of interesting conclusions have been arrived at. It is hoped that the results will be ready for publication in the course of the present year.

Thermometers.—An apparatus for the comparison of meteorological maximum and minimum thermometers in the horizontal position has been designed by Mr. Casella, and is at present under construction.

Seismograph.—An application for a grant of £60 for the purchase and erection of a seismograph was favourably entertained by the Government Grant Committee. The instrument has been ordered from Mr. R. Munro, but has not yet been delivered.

During 1897 the air temperature ranged from 21°·8 on December 25 and 26, to 87°·7 on August 4. The mean for the year was 50°·1. The maximum temperature in the sun's rays (black bulb *in vacuo*) was 143° on June 24, and the minimum on the grass was 16° on March 30: 1575 hours of bright sunshine were recorded, giving a mean percentage of 32, which is 3 per cent above the average for the 20 years 1877-96. The sunniest month was May, with a mean percentage of 54; whilst November, with only 10 per cent, was 10 per cent below the average for that month. The total rainfall was 21·835 ins., being 2·2 ins. below the average for past 35 years; March with 3·61 ins. and October with 0·58 in., giving the extreme values. The fall for October was phenomenally small, and is the lowest yet recorded here for that month.—*March* 1, 1898.

RADCLIFFE OBSERVATORY, OXFORD.—A. A. Rambaut, M.A., D.Sc., Radcliffe Observer.

During the year this Observatory has suffered the loss by death of its eminent and distinguished director, Mr. E. J. Stone, M.A., F.R.S., who for the last nineteen years had conducted its affairs with such success. Mr. Stone had also for many years been a member of the Meteorological Council.

Dr. Rambaut, late Astronomer-Royal for Ireland, was appointed to succeed him as Radcliffe Observer, and assumed the direction of the Observatory on October 20.

During the interval which elapsed between the death of Mr. Stone on May 9, and his successor's assuming the duties of Radcliffe Observer in October, the affairs of the Observatory were conducted by the first assistant, Mr. W. Wickham, on the same lines as in recent years, and the routine work has thus suffered no break of continuity notwithstanding the changes which have occurred.

Reports of the observations have been regularly sent, as heretofore, to the Meteorological Office (by telegram), the Registrar-General, the local newspapers,

the *Windsor Chronicle* (rainfall only), and to sanitary and other authorities upon request.

The following are the chief characteristics of the weather noted at Oxford in the year 1897 :—

The mean reading of the barometer for the year was 29·739 ins., or 0·015 in. above the mean for the last 42 years. The highest reading was 30·488 ins. on November 21, and the lowest 28·481 ins. on March 3, the range being 2·007 ins.

The mean temperature of the air was 49°·6, being 0°·8 above the mean for the preceding 69 years, and identical with the mean temperature for the year 1896. The maximum in the air was 85°·6 on August 4 ; the minimum, 21°·2 on December 24 ; and the lowest on the grass, 15°·8 on January 24.

Bright sunshine amounted to 1530 hours during 1897, being 94 hours above the average for the preceding 17 years ; the records for July and August show 64 and 27 hours respectively above the average.

The total rainfall for the year amounted to 27·192 ins. on the ground, being 0·941 in. above the mean for the preceding 82 years. There were altogether 142 "rainy days," or when 0·010 in. or more fell in the 24 hours. Whilst for the first 8 months an excess of rainfall amounting to 3·429 ins. was registered, on the other hand the records for September, October, and November exhibit a defect from the average rainfall of 3·058 ins., a nearly similar amount. On July 20 a severe thunderstorm occurred and was accompanied by unusually heavy rain, for between 3.55 and 4.55 p.m., no less than 1·515 ins. fell, flooding low-lying areas of the city.

The four platinum resistance thermometers acquired at the end of the year 1896 have been supplemented by two others ; one has been placed 10 feet below the surface of the soil, whilst the other has been used in the observing room for comparison with mercurial thermometers and for other purposes. These thermometers and the associated resistance apparatus are exceedingly sensitive and delicate, and certain initial difficulties have been encountered in getting them into working order. The solution of these difficulties and the determination of the fundamental points of the scale for each thermometer have necessarily consumed a large amount of time ; but a good deal of light has been thrown on some interesting details connected with them.—*February* 2, 1898.

THE CANADIAN METEOROLOGICAL SERVICE, TORONTO.—R. F. Stupart, Director.

The Director of the Magnetic Observatory, Toronto, is also Director of the Meteorological Service of the Dominion of Canada.

All meteorological observers in Canada who furnish reports to the Central Office are supplied with the necessary instruments by the Government. The following is the classification of stations :—

Chief Stations, where all the ordinary observations are taken day and night at equal intervals of time not exceeding four hours.

Telegraph Reporting Stations, where all the ordinary observations are taken three times daily at the same absolute time, namely, 8 a.m., 3 p.m., and 8 p.m., 75th meridian time, and the first and last are reported by telegraph as soon as taken to the Central Office at Toronto.

Ordinary Stations of the First Class, where all the ordinary observations are taken three times daily at certain local times.

Ordinary Stations of the Second Class, where regular observations of temperature, extremes of temperature, the direction and velocity of the wind, and the state of the weather, are taken three times daily at regular local times, the rainfall and snowfall also being measured.

Ordinary Stations of the Third Class, where records are kept of the fall of rain and snow and the general state of the weather.

Classification of Canadian Stations compared with that proposed by the International Conference.—There is but one station in Canada, namely, the Magnetic Observatory at Toronto, at which continuous records of barometric pressure, and of the temperature of the air, and of evaporation, as well as of the direction and velocity of the wind are kept by self-registering apparatus; and this station is properly the only one which fulfils the conditions necessary to entitle it to be ranked as a "Station of the First Order," according to the International programme.

The Chief Stations as regards the frequency of their observations, and also on account of the fact that nearly all of them are furnished with self-recording anemographs, should, however, take a rank superior to those of stations of the "Second Order," but they cannot properly be regarded, excepting in a partial sense, as stations of the "First Order."

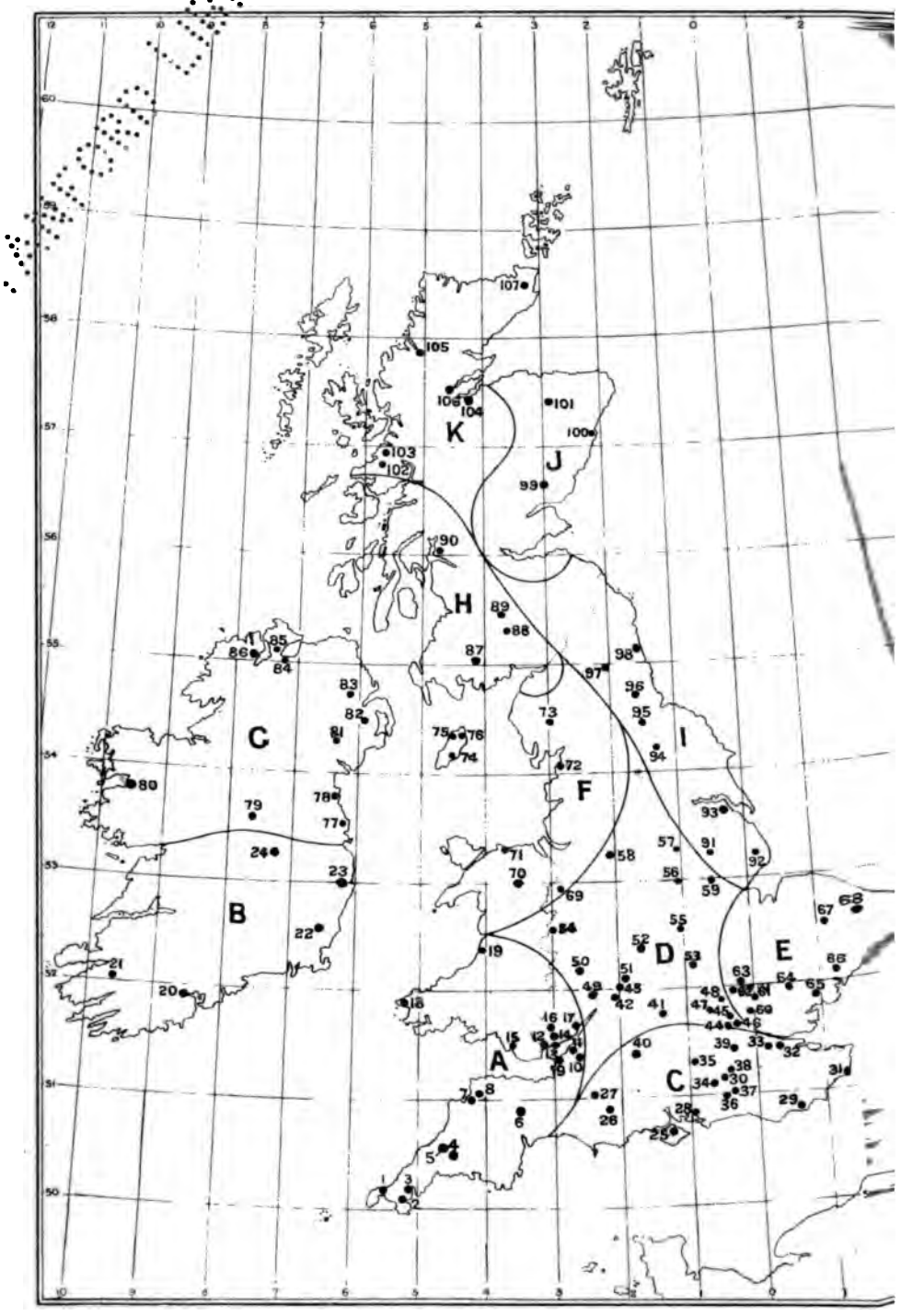
Telegraph stations and ordinary stations of the first class correspond to stations of the "Second Order" in the International classification, while ordinary stations of the second and third classes in the Canadian classification are to be reckoned as stations of the "Third Order."

Observers at Chief Stations, Telegraph Reporting Stations, and some few special stations are paid for the work performed by them, but the great majority perform the work voluntarily in the interest of science. There are at present in the Dominion 6 Chief Stations, 63 Class I., 163 Class II., and 83 Class III. At 15 stations a continuous record of bright sunshine is kept, and 21 stations are provided with electrical anemographs.[1]

The Telegraph Reporting Stations number 32, situated at nearly equal intervals between Victoria, B.C., and Sydney, Nova Scotia. At the majority of these, three observations are taken each day; at 8 a.m., 3 p.m. and 8 p.m., 75th meridian time, and the first and third are telegraphed by means of a code to the Central Office. Reports are also received once each day from Bermuda and St. Johns, Newfoundland. The reports comprise the barometer readings reduced to sea level, the readings of the dry and wet thermometers, the direction and velocity of the wind and state of the weather, the precipitation (if any), and with the morning report the minimum temperature of the preceding 12 hours, and with the evening report the maximum of the preceding 12 hours. Almost invariably all reports from stations between Lake Superior and Cape Breton are received in the Central Office by 8.40 a.m. and p.m., and are then forwarded without delay to the United States Weather Bureau at Washington, *via* Buffalo, N.Y., from which place some 60 United States stations are in return sent to Toronto, together with the Canadian reports from Manitoba westward to British Columbia, which are turned over to the United States Bureau at St. Paul, Minnesota. All reports are usually received shortly after 9.30, and the working chart is ready for the forecasting official by 9.45, and by 10 o'clock the isobars have been drawn and some of the forecasts telegraphed to their destination. The bulletin issued at night comprises a short synopsis of the weather during the past day, and generally a description of the existing meteorological conditions, then a list of the highest and lowest temperatures reported from about a dozen stations, followed by the forecasts for the various districts lying between Manitoba and the Maritime Provinces. These forecasts are for the 24 hours beginning the following 8 a.m., unless it be expressly stated that they cover a longer period. That same evening the telegraph company sends the bulletin to all points where are published morning news-

[1] A description of the instruments used and the exposure will be found in the *Annual Report* of the Service, year 1895.

MAP SHOWING POSITION OF THE PHENOLOGICAL STATIONS, 1897.



For the Names of the Stations see List of Observers, Page 131.

papers, in which it is printed generally at the head of the column of local news, and then in the morning, on the opening of the various telegraph offices throughout the Dominion, the first message which goes over the wires is the daily forecast, which is posted up in a conspicuous place in every telegraph office. Up to the summer of 1894 the forecast based on the 8 p.m. chart was practically the only one issued, but since that time a second forecast, generally covering the current and following day, has been issued at 10 a.m.; this is made more especially for the benefit of sailors and fishermen, and is sent to nearly all ports both on the Great Lakes and on the seaboard; recently arrangements have been made whereby it appears in most of the afternoon newspapers published in the Dominion.

There are in the Dominion 67 stations at which cautionary and storm signals are displayed, 33 on the Lakes, and 34 in the Maritime Provinces. The signals used are drums and cones—the cone alone being hoisted when but a moderate gale is expected, and both drum and cone together when it is thought that the storm will be heavy; the apex of the cone downwards indicates Southerly and Easterly directions, and upwards Northerly and Westerly.

As a means of disseminating more generally the forecasts among the farming community during the summer season, white discs indicating "Fine," "Showers," or "Rain" are placed each morning on the baggage vans of outgoing trains; it is proposed to greatly extend this system during the coming year.

Each morning some 75 copies of the *Weather Chart* are made by means of a duplicating machine, the mimeograph, and supplied to a few subscribers, to the Toronto newspapers, to the Board of Trade, and to such business people who engage to post them where they will be seen by the public. This chart is ready for distribution at 11 a.m. Up to the present no forecasts have been made for British Columbia and the North-west Territories near the Rocky Mountains, but it is hoped that before very long a chart will be made at Victoria simultaneously with that in Toronto, and forecasts will then be issued in our Pacific Province.

Publications.—The regular publications of this service are an *Annual Report*, a *Monthly Weather Review*, and a *Monthly Weather Map* which is based chiefly on telegraphic reports, and is issued about five days after the close of each month, also the *Toronto Annual Meteorological Register*. The *Annual Report* is at present lamentably in arrears, but those for the years 1890 and 1895 will very shortly be issued, that for 1896 will follow with little delay, and 1897 in due course, while the missing years 1891 to 1894 will be issued as soon as possible.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1897.

By EDWARD MAWLEY, F.R.H.S., Secretary.

(Plate III.)

[Read February 16, 1898.]

The changes that have taken place in the list of observers since the last report was issued are as follows. No returns were received from Wye, Westgate-on-Sea, or Farley in District C; Uppingham and Tean in District D; Hatfield in District E; Penmaenmawr and Giggleswick in District F; Clonbrock in District G; Tynron in District H; Lilliesleaf in District I; and Lhanbryde in District J. On the other

hand, new stations have been started at Altarnon in District **A**; Havant in District **C**; Ellesmere in District **F**; Claxby and Thirsk in District **I**; and Invermoidart, Roshven, and Watten in District **K**. In order to make the organisation more complete new observers are at the present time much needed in the south of Ireland, and the west and east of Scotland, as well as in the following counties of England and Wales, viz. Anglesea, Bedford, Berks, Brecknock, Carmarthen, Cumberland, Denbigh, Derby, Montgomery, Radnor, Stafford, and Worcester.

The averages used for the different plants in the present report are the same as those employed for 1896. The observations for another twelvemonth are now available, but the early and late seasons were so evenly balanced in the six years, 1891-96, that it was considered inadvisable, for the present at all events, to calculate the averages afresh.

It will be seen from Table I., that taking all the plants on the list, the flowering season of the past year was, if anything, rather an early one.

TABLE I.—MEAN RESULTS, WITH THEIR VARIATIONS FROM THE SIX YEARS' AVERAGE (1891-96), FOR THE THIRTEEN PLANTS IN ALL THOSE DISTRICTS WHERE THERE HAVE BEEN THROUGHOUT THE SEVEN YEARS (1891-97) SUFFICIENT OBSERVATIONS TO WARRANT COMPARISONS BEING MADE.

Years.	Eng. S.W.		Eng. S.		Eng. Mid.		Eng. E.		Eng. N.W.	
	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.
		Days.		Days.		Days.		Days.		Days.
1891	144	+12	144	+11	150	+12	147	+13	150	+10
1892	139	+ 7	138	+ 5	144	+ 6	143	+ 9	147	+ 7
1893	118	-14	122	-11	125	-13	123	-11	128	-12
1894	126	- 6	130	- 3	135	- 3	127	- 7	137	- 3
1895	139	+ 7	138	+ 5	141	+ 3	138	+ 4	144	+ 4
1896	125	- 7	128	- 5	132	- 6	130	- 4	134	- 6
1897	130	- 2	132	- 1	136	- 2	132	- 2	142	+ 2
Mean	132	...	133	...	138	...	134	...	140	...

Explanation of the Dates in the Tables.

1- 31	are in	January.	182-212	are in	July.
32- 59	,,	February.	213-243	,,	August.
60- 90	,,	March.	244-273	,,	September.
91-120	,,	April.	274-304	,,	October.
121-151	,,	May.	305-334	,,	November.
152-181	,,	June.	335-365	,,	December.

The Winter of 1896-97.

Taken as a whole, this was rather a cold winter than otherwise in all parts of the British Isles. In January the mean temperature ranged from $-2^{\circ}\cdot8$ in England South to $-4^{\circ}\cdot0$ in Ireland South; whereas during February the weather was in many districts nearly as warm as in the previous month it had been cold. Throughout Scotland and the greater part of Ireland the rainfall was below the average, but in England this proved a wet quarter. There was a deficient record of

sunshine in most parts of the Kingdom, and especially was this the case during February.

The frequent rains of December put a stop to the sowing of winter corn. Fortunately the preceding month had been so favourable throughout that little more remained to be got in. Indeed, the wet weather, by rendering the surface soil firm round the young plants, proved beneficial to the later sown wheat. The one drawback at this period, as pointed out by Sir J. B. Lawes, F.R.S., in his report on the wheat crop of 1897, was the impoverished condition of the land, owing to the exceptionally large quantity of nitric acid washed out of it by the heavy rainfall of September and October. The latter half of January continued very cold; indeed, this was the only really cold period of the winter, but only here and there were any very low temperatures registered; while a moderately deep fall of snow protected much of the young wheat, and more particularly the winter beans, from injury from frost and bitter winds. The mild weather which prevailed after the second week in February was very favourable to the corn, and allowed of a good supply of keep being maintained in the fields for the cattle and sheep—a matter of unusual importance to the farmer, owing to the deficient yield both of hay and roots in the previous year.

At no time during the season was there any lack of green vegetables in the kitchen garden; and in the warmer parts of the country, roses and other flowers were to be seen in blossom nearly up to Christmas. Such early plants as the winter aconite did not come into flower as soon in the new year as had been anticipated, owing to the cold spell in January.

Taking the British Isles as a whole, the fertile flowers on the hazel first appeared 5 days in advance of the average date for this plant; while the coltsfoot was in blossom 10 days earlier than the mean date for the six years, and 1 day earlier than in any of those years.

The song-thrush was first heard after the beginning of the year 7 days in advance of its usual time. The honey bee first visited flowers 1 day earlier than the mean date.

The Spring.

March proved a warm spring month, but both April and May were more or less below the average in temperature in all parts of the country —the departures from the mean during these two months being greatest in the north of England and Ireland and throughout Scotland. The rainfall in March and April was unusually heavy, but in the southern half of these islands scarcely any rain fell during May until the end of the month, while in the northern districts the total fall was also in defect of the mean. There was almost everywhere a deficiency of sunshine in March; but for the rest of the season the record was unusually good.

On the farm this was one of the worst sowing seasons known for some years, owing to the persistent rainfall in the early part of it and the frequent showers afterwards. In many parts of England a good deal of grain had been got in during a favourable period at the end of February, but in the late districts all farm work throughout March and

April remained extremely backward. This wet period was followed by a cold drought which held until nearly the end of May. The dry weather lasted only a few weeks, but the previous rains had left the ground in such a sodden condition that when they were succeeded later in May by strong North-easterly winds it became so caked on the

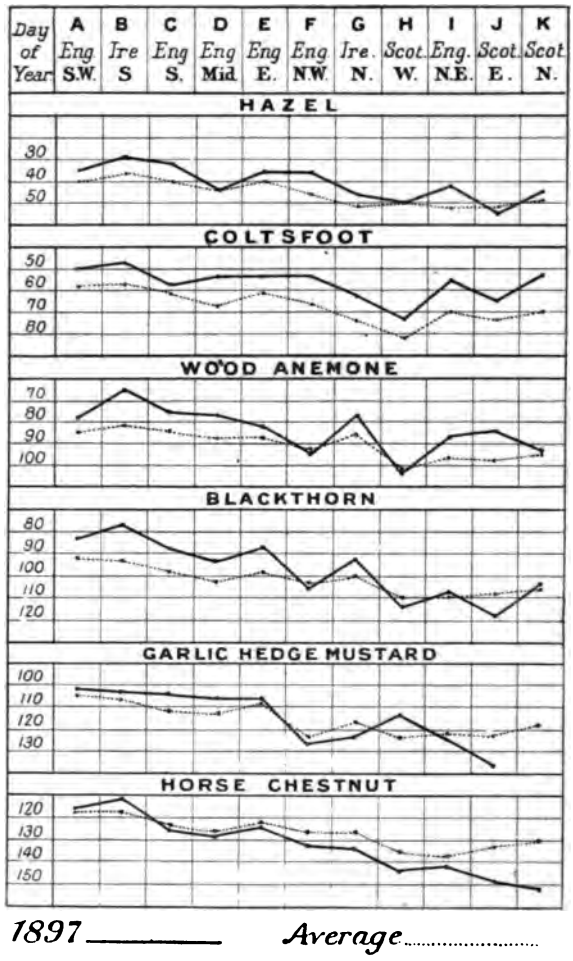


FIG. 1.—Mean dates (day of year) of flowering of plants in 1897 as compared with the six years' average 1891-96.

surface as to be, at all events, on the heavier soils, almost as unworkable as before, so that the return of rain at the end of that month was greatly welcomed, especially as it brought with it a change of wind to a more genial quarter.

In the gardens good progress was made by vegetation during March, owing to the steady warmth of the ground, and to the absence of frosty nights. The usual cold period in May was very marked, and it was during the succession of frosty nights which occurred at this time, that

in many localities much of the abundant blossom on the fruit trees was injured.

A large number of trees were blown down by a South-westerly gale which swept over the south of England on March 2. In most parts of the country the flowers on the hawthorn appear to have been remark-

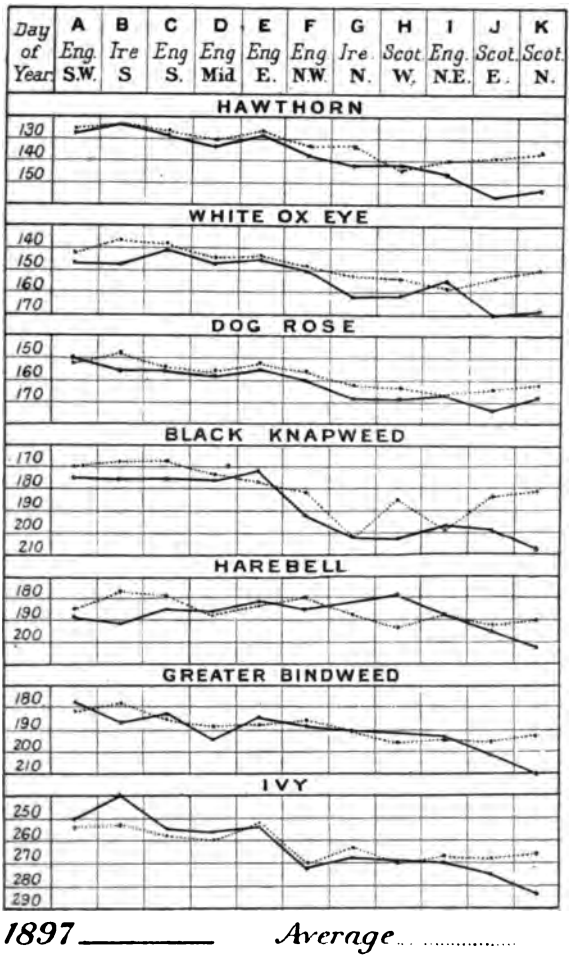


FIG. 2.—Mean dates (day of year) of flowering of plants in 1897 as compared with the six years' average 1891-96.

ably scanty. This was no doubt in some measure due to the singularly heavy crop of berries they bore in 1896, as well as to the late growth they made in that year, and the unripened state of the young shoots at the end of the autumn. In most districts there was a singular absence of greenfly on roses and other plants.

There was nothing very exceptional in the dates of flowering of any of the spring plants, except the wood anemone, which has only once in the previous six years been as early. The blackthorn blossomed 5 days

earlier, and the garlic hedge mustard 1 day earlier than their respective mean dates. But after this time the lower temperatures in April and May began to make themselves felt, and the remaining plants flowering in the spring were behind their usual time, the horse-chestnut and hawthorn being both 5 days late.

Of the spring migrants on the list the swallow made its appearance 1 day earlier than the average date, while the nightingale was 1 day early, and the flycatcher 2 days early; the cuckoo, on the other hand, arrived 2 days late.

The wasp was first seen 4 days earlier than usual; whereas the small white butterfly was 13 days late, and the orange tip butterfly 2 days late.

The Summer.

The summer of 1897 was everywhere a warm one, the departure in mean temperature from the average varying from + 0°·8 in Ireland North to + 2°·4 in the southern counties of England. June and August were both more or less unseasonably wet, but, on the other hand, during July very little rain fell. June proved less sunny than usual, but throughout the rest of the season there was a splendid record of clear sunshine.

With the advent of June came a marked improvement in the appearance of the corn and other crops, while the roots and grass were especially benefited by the warm rains which fell from time to time during the course of it. The crop of hay in England and Wales was a heavy one, and in most districts was harvested in excellent condition; but in Scotland the yield was not much above the average.

Some mention should be made here of the disastrous hailstorm which occurred on June 24 in the neighbourhood of Chelmsford in Essex, an interesting account of which will be found in *Symons' Meteorological Magazine* for July 1897. Previous to the storm the crops in the locality in which it occurred were looking unusually promising, when, "in less than twenty minutes," says the *Times'* special correspondent, "the whole prospect was utterly destroyed, and the crops were as completely gone as last winter's snow." Not only were the field plants destroyed by the driving hail, but many trees were overturned by the violence of the wind, and others that had survived lost a great part of their foliage. Over 100 square miles are stated to have been covered by the disaster.

For the corn crops the weather during July was on the whole most favourable, owing to the dry weather and the warmth afforded the ground by the brilliant sunshine. It also favoured the ingathering of an unusually heavy crop of hay in the later districts under the most satisfactory conditions. Towards the end of the month, however, rain was becoming greatly needed by the roots and pastures. The fact is the land had become so beaten down and run together on the surface by the previous heavy rains, that plants suffered more during this second drought than they would otherwise have done.

During the first half of August a great deal of corn was got in, but later in the month, the frequent rains, although welcomed for the sake of the roots and grass, interfered greatly with harvest work in the later districts of England, as well as throughout Scotland and Ireland.

The absence in most localities of sharp frosts in the late spring and

early summer, caused the vegetables and flowers in the gardens to grow on without check until about the middle of July, when the drought began to make itself felt, especially by the lawns, which at the end of the month had become quite brown.

Throughout the season there were comparatively few wasps or butterflies.

All the summer plants on the list flowered later than usual, the white ox eye being 7 days late, the dog rose 4 days late, the black knapweed 8 days late, the harebell 2 days late, and the greater bindweed 3 days late.

The meadow brown butterfly made its appearance 4 days later than usual.

The Autumn.

This was not only a warm, but also a very dry autumn. September proved cold; but taking October and November together, the variation from the average in mean temperature ranged from + 1°·4 in England East to + 3°·8 in Scotland West. In the same two months there was also a very scanty rainfall, except in Ireland South. The records of sunshine varied considerably in the different districts, but in most of them this was rather a sunless quarter.

At first the harvest promised to be a remarkably speedy one, and so it proved in the earliest districts. The rainy period, however, which set in after the middle of August and lasted until the end of the first week in September, caused great delay in the more backward districts in England, and the greater part of Scotland and Ireland. Indeed, at the end of this period a good deal of corn had not even been cut, while much more remained still uncarried in the fields. Fortunately the damage done by the rain was not nearly as great as had been anticipated, and by the end of the third week in September the whole had been secured. This was a most favourable season for the root crops and grass, the short rainy period at the beginning of it being succeeded by fine weather and abundant sunshine. Seldom has there been an October so favourable for the sowing of wheat and other winter crops, and seldom has it been necessary to expend so little labour upon the preparation of the land. But in November, during the third drought of the year, the ground at last became so hard, through the continued dry weather, that it was not until rain came a little later on that tillage operations could be proceeded with.

In the flower garden this was a glorious autumn, particularly where dahlias and other delicate plants escaped injury from the frosts which occurred early in October, many plants, roses included, were still blossoming freely at the end of the season. Owing to the dry sunny weather in October the young shoots on the fruit trees became satisfactorily matured at an unusually early period. Apples and pears also ripened earlier than usual, and the former, although small, were remarkably well coloured.

There were but few wild fruits, with the exception of blackberries and nuts, which were almost everywhere very plentiful. Favoured by the continued dry weather and the absence of keen frosts, deciduous trees retained their leaves until an unusually late date, while the autumn tints were almost everywhere remarkably fine.

According to the preliminary statement issued by the Board of Agriculture showing the estimated yield of the three leading corn crops in Great Britain, oats exceeded the average for the previous ten years by ·36 bushel per acre, while the crop of barley was an exact average, and wheat ·40 bushel per acre below average. Taking Scotland alone, however, all three crops are there represented as exceeding the ten years' mean, and especially was this the case with wheat. In the Report issued by the Registrar-General for Ireland all the cereals are stated to have yielded crops rather under the average, that of barley being the most deficient of the three; wheat and oats are reported as having yielded good average crops. Taking the United Kingdom as a whole the remaining farm products, such as beans, potatoes, and turnips were about average; while peas and mangolds were above average. There was little potato disease in Great Britain; but in Ireland, where the potatoes at one time promised so well, they were reduced by it to about half a crop.

This was a very poor year for fruit. The only good crop was that of strawberries; the other small fruits were very variable, but on the whole about average; while apples, pears, and plums, especially the latter, yielded very indifferently. In order to ascertain the causes which led to these failures, we must go back to the dry spring and summer of 1896, which for the time crippled the growth of the trees, and then to the wet and sunless autumn of that year, which did not allow of the shoots they had made becoming properly ripened. So that although in most places the blossoms were abundant, they were not perfectly formed, and consequently fell easy victims to the cold winds and low temperatures of the following spring.

The ivy came into blossom at its average time, but later than in the two previous years.

The dates for the departure of the swallows are somewhat irregular, but, taking all the records sent in, they were 2 days early in leaving this country.

The Year.

There was nothing very exceptional about the weather of the past phenological year, as regards its effects on vegetation, beyond the heavy rains in March and the three dry periods of May, July, and October. Until about the middle of May wild plants came into blossom in advance of their usual time, but throughout the rest of the flowering season they were more or less behind their mean dates in coming into bloom. Unlike the previous year the crop of wild fruits was very poor, with the exception of blackberries and nuts, which were unusually plentiful.

The heavy rainfall in the spring favoured the hay, which proved the only really abundant farm crop of the year, but greatly retarded the sowing of spring corn. The cereals were, however, much benefited later on by the warm, dry, and brilliant weather of the summer. Taking the British Isles as a whole, the crop of oats was a fairly good one, that of barley being about average, while the yield of wheat was somewhat under average. There were also fair crops of roots and potatoes. Apples, pears, and plums, and especially the latter, yielded badly, while the small fruits were about average.

TABLE II.—List of the Stations with the Names of the Observers.

Station.	County.	Height above Sea-level.	Observer.
A		Ft.	
1. Marazion	Cornwall	40	F. W. Millett.
2. Mawnan	Cornwall	200	Miss R. Barclay.
3. Falmouth	Cornwall	190	Miss Willmore.
4. Liskeard	Cornwall	400	S. W. Jenkin, C.E.
5. Altarnon	Cornwall	570	C. U. Tripp, M.A., F.R.Met.Soc.
6. Tiverton	Devon	270	Miss M. E. Gill.
7. Westward Ho	Devon	130	Miss Patterson.
8. Barnstaple	Devon	90	T. Wainwright.
9. Sidcot	Somerset	200	W. F. Miller.
10. Long Ashton	Somerset	280	Miss H. Dawe.
11. Clifton	Gloucester	300	G. C. Griffiths, F.E.S.
12. Penarth	Glamorgan	120	G. A. Birkenhead.
13. Cardiff	Glamorgan	40	A. A. Pettigrew, F.R.H.S.
14. Castleton	Glamorgan	80	F. G. Evans, F.R.Met.Soc.
15. Bridgend	Glamorgan	90	H. J. Randall, Junr., F.R.Met.Soc.
16. Bassaleg	Monmouth	125	W. J. Grant, F.R.H.S.
17. St. Arvans	Monmouth	360	Miss M. Peake.
18. St. Davids	Pembroke	220	W. P. Propert, LL.D., F.R.Met.Soc.
19. Aberystwith	Cardigan	30	J. H. Salter, D.Sc.
B			
20. Cork	Cork	100	R. A. Phillips.
21. Killarney	Kerry	100	Ven. Archdeacon Wynne, D.D.
22. Ferns	Wexford	260	G. E. C. Greene, M.A., D.Sc., F.L.S.
23. Glendalough	Wicklow	460	Mrs. W. Wynne.
24. Geashill	King's County	280	Rev. Canon Russell.
C			
25. Bembridge	Isle of Wight	80	C. Orchard, F.R.H.S.
26. Blandford	Dorset	270	J. C. Mansell-Pleydell, F.G.S., F.L.S.
27. Buckhorn Weston	Dorset	290	Miss H. K. H. D'Aeth.
28. Havant	Hants	30	H. Beeston.
29. Bexhill-on-Sea	Sussex	10	H. Le Mesurier Dunn.
30. Muntham	Sussex	250	P. S. Godman, F.Z.S.
31. Dover	Kent	150	F. D. Campbell.
32. Swanley	Kent	160	C. H. Hooper.
33. Chislehurst	Kent	360	Miss F. Duncan.
34. Coneyhurst	Surrey	600	J. Russell.
35. Churt Vicarage	Surrey	350	Rev. A. W. Watson.
35. Churt	Surrey	300	C. Criddle.
36. Chiddingfold	Surrey	230	Vice-Admiral Maclear, F.R.Met.Soc.
37. Winterfold	Surrey	580	R. Turvey.
38. Oxshott	Surrey	210	W. H. Dines, B.A., F.R.Met.Soc.
39. East Molesey	Surrey	40	Lady Jenkyns.
40. Marlborough	Wilts	480	E. Meyrick.
D			
41. Oxford	Oxford	200	F. A. Bellamy, F.R.Met.Soc.
42. Cheltenham	Gloucester	250	M. L. Evans.
43. Beckford	Gloucester	120	F. Slade, F.R.Met.Soc.
44. Watford	Herts	240	Mrs. G. E. Bishop.
45. St. Albans (The Grange)	Herts	380	Mrs. Hopkinson.
45. St. Albans (Addiscombe Lodge)	Herts	400	Miss E. F. Smith.
45. St. Albans (Worley Road)	Herts	300	H. Lewis.

TABLE II.—List of the Stations with the Names of Observers.—*Continued.*

Station.	County.	Height above Sea-level.	Observer.
		Ft.	
46. Radlett	Herts	320	Miss E. M. Lubbock.
47. Berkhamsted	Herts	400	Mrs. E. Mawley.
48. Harpenden	Herts	370	J. J. Willis.
49. Ross	Hereford	210	H. Southall, F.R.Met.Soc.
50. Leominster	Hereford	220	J. H. Arkwright.
51. Evesham	Worcester	120	Rev. D. Davis, B.A.
52. Ullenhall	Warwick	400	Mrs. Coldicott.
53. Northampton	Northampton	320	H. N. Dixon, M.A., F.L.S.
54. Churchstoke	Montgomery	550	P. Wright, F.R.Met.Soc.
55. Thurcaston	Leicester	250	Rev. T. A. Preston, M.A., F.R.Met.Soc.
56. Beeston	Notts	210	G. Fellows.
57. Hodsock	Notts	60	Miss Mellish, F.R.H.S.
58. Macclesfield	Cheshire	500	J. Dale.
59. Belton	Lincoln	200	Miss F. H. Woolward.
E			
60. Wormley	Herts	120	A. Warner.
61. Hertford	Herts	140	W. Graveson.
62. Hitchin	Herts	230	J. E. Little, M.A.
63. Ashwell	Cambridge	260	H. G. Fordham.
64. Bocking	Essex	240	H. S. Tabor, F.R.Met.Soc.
65. Lexden	Essex	90	Miss Carver.
66. Sproughton	Suffolk	30	Rev. A. Foster-Melliar.
67. Tacolneston	Norfolk	190	Miss E. J. Barrow.
68. Brundall	Norfolk	70	A. W. Preston, F.R.Met.Soc.
F			
69. Ellesmere	Shropshire	340	Miss D. F. Jebb.
70. Palé	Merioneth	600	T. Ruddy.
71. Conway	Carnarvon	100	A. T. Johnson.
72. Claughton	Lancashire	80	Mrs. Kent Green.
73. Ambleside	Westmoreland	260	Miss M. L. Hodgson.
74. Cronkbourne	Isle of Man	110	A. W. Moore. J. Murphy.
75. Orry's Dale	Isle of Man	70	Miss C. M. Crellin.
76. Sulby	Isle of Man	80	H. S. Clarke, F.E.S.
G			
77. Ardgillan	Dublin	210	Capt. E. R. Taylor, F.R.Met.Soc.
78. Piperstown	Louth	320	Miss E. Smith.
79. Edgeworthstown	Longford	270	J. M. Wilson, M.A.
80. Westport	Mayo	10	J. M. McBride.
81. Loughbrickland	Down	350	Rev. H. W. Lett, M.A.
82. Saintfield	Down	310	Rev. C. H. Waddell, M.A.
83. Antrim	Antrim	70	Rev. W. S. Smith.
84. Hazelbank	Londonderry	450	T. Gibson.
85. Ballynagard	Londonderry	30	Miss A. M. Campbell.
86. Ramelton	Donegal	200	Miss K. Swiney.
H			
87. New Galloway	Kirkcudbright	450	T. R. Bruce.
88. Thornhill	Dumfries	300	J. Fingland.
89. Jardington	Dumfries	100	J. Rutherford.
90. Helensburgh	Dumbarton	100	Miss Muirhead.

TABLE II.—List of the Stations with the Names of Observers—*Continued.*

Station.	County.	Height above Sea-level.	Observer.
I		Ft.	
91. Doddington .	Lincoln . .	90	Rev. R. E. Cole.
92. Claxby . .	Lincoln . .		Rev. H. M. W. Hinchliff.
93. Great Cotes .	Lincoln . .	30	J. Cordeaux.
94. Thirsk . .	Yorks (N.R.) .	120	A. B. Hall.
95. East Layton .	Yorks (N.R.) .	570	Mrs. E. O. Maynard Proud.
96. Durham . .	Durham . .	350	H. J. Carpenter.
97. Corbridge-on-Tyne	Northumberland	200	A. W. Price.
98. Cambois . .	Northumberland	20	S. Dunnett.
J			
99. Kirriemuir .	Forfar . .	250	T. M. Nicoll.
100. Aberdeen . .	Aberdeen .	40	P. Harper.
101. Newmill . .	Banff . .	350	J. Ingram.
K			
102. Invermoidart .	Inverness . .	60	Symers M. Macvicar.
103. Roshven . .	Inverness . .	40	Hugh Blackburn.
104. Beauly . .	Inverness . .	60	A. Birnie.
105. Inverbroom .	Ross . .	50	J. A. Fowler.
106. Dingwall . .	Ross . .	10	J. P. Smith, M.D.
107. Watten . .	Caithness . .	150	Rev. David Lillie.

The numbers before the names of the stations refer to their position on the map of the stations, Plate III.

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1897.

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
A													
Marazion . .	12	34	...	67	...	...	119	157	143	184	...	178	256
Mawnan . .	34	65	...	76	101	113	125	...	160	188	...	...	252
Falmouth . .	38	36	...	60	103	...	118	...	143	...	...	173	252
Liskeard . .	44	...	78	73	...	118	118	...	...	...	...	...	...
Altarnon . .	32	69	101	100	109	124	147	160	163	179	...	...	...
Tiverton . .	48	58	78	83	95	102	120	142	150	165	..	...	263
Westward Ho .	56	...	...	...	104	118	124	*122*	*125*	194	...	190	290
Barnstaple . .	14	46	83	78	85	122	126	146	143	180	195	169	253
Sidcot . . .	25	51	80	82	98	114	135	143	157	167	...	177	...
Long Ashton .	31	54	79	108	111	114	128	146	148	...	171	165	...

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1897—*Continued.*

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
Clifton	...	...	80	88	...	123	127	...	153	...	...	...	269
Cardiff	45	45	...	...	...	110	...	...	...	...	...	...	...
Castleton	37	43	61	83	107	113	130	141	151	168	198	175	265
Bridgend	54	...	...	102	...	...	117	...	...	...	...	...	...
Bassaleg	38	38	78	84	104	112	126	137	147	161	...	170	254
St. Arvans	39	...	69	93	103	121	136	...	144	165	...	193	248
St. Davids	...	...	...	*122*	...	125	132	*168*	...	186	...	189	...
Aberystwith	20	56	84	79	99	123	125	145	154	166	...	...	...
B													
Cork	...	...	56	73	...	...	109	...	164	171	...	171	...
Killarney	12	38	56	58	98	84	115	143	145	*195*	191	183	244
Ferns	39	50	*90*	82	...	122	130	145	155	170	...	187	257
Glendalough	36	56	80	88	105	128	138	144	149	183	...	204	236
Geashill	*2*	45	69	82	107	*136*	...	154	163	180	...	...	258
C													
Bembridge	41	35	...	83	...	116	115	132	...	...	...	...	...
Blandford	32	56	74	90	*122*	130	123	140	154	171	174	169	...
Buckhorn Weston	18	46	76	86	88	121	126	143	151	170	...	187	276
Havant	45	...	72	85	92	122	...	142	154	173	...	173	277
Bexhill-on-Sea	51	65	61	96	114	119	119	130	140	...	...	...	275
Muntham	25	53	69	82	97	113	122	135	149	159	...	184	278
Dover	...	...	...	...	...	114	138	...	165	181	...	...	256
Swanley	...	49	84	93	104	128	135	152	158	187	...	...	...
Chislehurst	6	51	73	88	110	119	139	148	152	181	199	190	266
Coneyhurst	43	58	79	104	...	137	131	140	161	188	185	182	243
Churt Vicarage	15	83	86	89	98	130	137	147	155	175	179	197	...
Churt	2	77	81	85	112	126	127	135	...	...	...	184	*227*
Chiddingfold	45	58	66	84	106	126	131	143	155	167	181	187	260
Winterfold	41	...	74	*128*	...	141	147	...	162	...	191	...	...
Oxshott	45	...	78	86	106	129	127	...	...	...	...	...	...
East Molesey	45	52	87	101	116	120	122	141	159	170	*203*	184	269
Marlborough	12	52	65	86	107	123	131	142	156	177	189	181	248
D													
Oxford	...	55	...	92	89	...	129	...	148	...	169	...	261
Cheltenham	31	45	65	...	103	122	137	150	153	171	197	206	269
Beckford	42	48	70	85	98	119	119	130	150	167	189	166	257
Watford	41	...	*93*	95	114	128	138	144	154	...	...	...	270
St. Albans (The Grange)	37	...	86	94	97	122	128	140	148	172	182	...	248
St. Albans (Addiscombe Lodge)	47	54	74	85	107	120	134	139	...	...	...	219	...
Radlett	56	...	...	...	...	...	...	...	...	...	...	...	...
Berkhamsted	45	48	85	103	109	130	...	141	154	177	193	184	266
Harpenden	46	64	79	87	105	135	130	147	155	*196*	197	199	...
Ross	44	57	...	80	87	124	130	151	...	...	...	...	...
Leominster	48	...	80	...	...	124	135	...	...	...	...	180	...
Evesham	35	41	...	83	89	121	120	135	...	...	...	...	...
Ullenhall	39	45	69	98	123	143	136	148	165	187	191	205	283

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1897—*Continued.*

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
hampton	52	51	70	99	114	128	134	155	160	175	187	214	252
rchstoke	44	59	76	95	120	140	142	145	165	185	182	189	...
rcaston	54	...	80	105	106	136	134	153	156	160	193	203	277
ton	43	62	...	106	*147*	133	139	161	166	176	171	...	...
sock	...	54	82	84	108	126	134	153	158	...	187	176	267
clesfield	47	75	97	107	134	144	143	162	174	188	190	191	272
on	41	53	65	91	111	126	126	152	167	182	186	*225*	272
E													
mley	38	49	...	...	...	...	...	...	...	...	...	...	...
ford	7	45	66	80	*63*	129	120	147	151	171	196	186	262
hin	38	50	76	81	99	121	118	135	...	...	171	191	274
well	38	54	...	...	...	...	129	...	154	...	...	...	259
cing	41	54	94	79	111	129	131	153	152	171	...	...	249
len	...	59	82	88	104	113	129	...	153	...	178	178	263
ughton	38	56	...	95	114	128	134	142	157	...	...	...	249
olneston	...	64	87	...	...	118	136	...	155	...	...	...	...
ıdall	52	54	80	102	106	129	135	144	165	...	...	185	276
F													
smere	...	52	...	...	...	...	...	...	...	...	...	...	...
	46	67	100	96	126	135	140	155	161	195	175	195	289
way	43	51	...	...	...	129	127	135	157	...	...	194	278
ghton	...	*80*	...	105	...	...	...	160	162	191	195	190	...
leside	7	51	80	110	127	142	140	...	154	191	181	191	*309*
ıkbourne	...	...	*125*	...	...	136	140	...	...	...	*129*	...	278
's Dale	49	46	102	108	...	112	143	148	164	...	187	171	...
G													
gillan	59	60	84	91	...	132	139	165	...	200	...	...	290
rstown	31	75	86	83	...	135	143	165	167	205	...	198	278
eworthstown	...	...	...	90	...	143	144	...	170	...	...	...	...
tport	45	...	*53*	90	...	96	131	...	...	...	...	...	259
ghbrickland	48	44	70	94	...	143	144	...	165	184	...	181	...
tfield	39	48	71	87	...	139	142	...	170	...	...	...	...
rim	50	...	61	94	122	...	142	159	...	...	...	...	285
elbank	...	63	94	113	...	144	148	...	173	212	...	...	...
ynagard	...	...	...	72	...	...	140	...	166	...	...	...	278
ielton	50	80	80	93	*179*	137	145	157	167	211	...	...	...
H													
Galloway	43	80	114	117	...	...	152	162	172	...	...	...	...
rnhill	52	...	...	112	...	...	...	...	...	...	...	...	...
ington	47	64	79	112	...	142	145	160	165	203	179	...	...
ensburgh	57	77	115	112	113	145	129	...	...	...	...	...	...
I													
dington	53	58	80	100	105	126	135	161	162	...	...	195	...
by	...	...	...	...	113	130	142	151	...	...	...	...	...

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1897—*Continued.*

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
Thirsk . .	38	46	78	87	112	136	137	143	159	...	191	184	296
East Layton .	...	...	...	122	131	152	153	...	170	...	...	...	...
Durham . .	...	61	88	110	141	153	153	*177*	177	...	183	...	...
Corbridge-on-Tyne	39	66	91	113	136	149	151	165	174	203	193	*219*	265
Cambois . .	39	44	104	118	...	148	150	157	160	191	186	201	...
J													
Kirriemuir . .	...	69	...	118	...	...	...	...	171	198	189	207	...
Aberdeen . .	...	71	78	...	...	148	150	*187*	180	...	203	...	...
Newmill . .	55	54	89	120	136	149	161	170	172	200	192	194	285
K													
Invermoidart .	...	...	100	...	...	...	...	173	171	*209*	...	...	...
Roshven . .	...	...	...	...	...	153	137	165	163	205	...	...	293
Beauly . .	53	65	104	123	...	150	...	...	...	...	...	...	...
Inverbroom . .	32	20	...	...	...	...	...	163	166	...	207	...	...
Dingwall . .	51	52	76	84	...	151	155	168	172	...	198	211	295
Watten . .	...	76	...	...	...	...	166	178	...	211	...	...	...

The dates in *italics* have not been taken into consideration when calculating the means given in Table IV.

Observers' Notes.

December 1896.—*Churt Vicarage* (C)—25th. Ten different kinds of flowers were in bloom in the Vicarage garden, including roses, primroses, and violets. *Berkhamsted* (D)—24th. The last rose bloom of the year was knocked to pieces by heavy rain, which is three weeks later than the average date of its destruction in the previous 11 years.

January 1897.—*Chislehurst* (C)—13th. Winter aconite in flower.

February.—*Long Ashton* (A)—26th. Wild daffodils in flower. *Bridgend* (A)—21st. Primrose in flower. *Aberystwith* (A)—15th. Frog spawn first seen. *Bembridge* (C)—25th. Asparagus just appearing above ground. *Blandford* (C)—13th. Frog spawn first seen. *Buckhorn Weston* (C)—17th. Last night several blackbirds were singing continuously from 10 p.m. to 2 a.m., and perhaps longer. It was a bright moonlight night after two sunny days. *Chislehurst* (C)—26th. Found a blackbird's nest with two eggs in it. *Berkhamsted* (D)—7th. Winter aconite in flower. There were erect flowers ready to open on January 6, but they were never able to expand until now, owing to the paucity of sunshine in the first instance and afterwards to the covering of snow. *Hodsock* (D)—9th. Winter aconite in flower. *Wormley* (E)—28th. A fully completed robin's nest was found in an old canary breeding cage hanging on one of our outbuildings. *Ashwell* (E)—28th. Rooks building. *Loughbrickland* (G)—27th. Frog spawn first seen. *Beauly* (K)—3rd and 4th. Severe frost which injured laurels, but low-growing plants were protected by a foot of snow, which fell at the end of the previous month.

LE IV.—MEAN DATES (DAY OF YEAR) FOR THE FIRST FLOWERING OF PLANTS N 1897, AND THEIR VARIATIONS FROM THE SIX YEARS' AVERAGE (1891-96).

PLANTS.	A England, S.W.			B Ireland, S.			C England, S.			D England, Mid.		
	1897.	Average for Six Years.	Variation from Average.	1897.	Average for Six Years.	Variation from Average.	1897.	Average for Six Years.	Variation from Average.	1897.	Average for Six Years.	Variation from Average.
zel	35	40	− 5	29	*36*	− 7	31	40	− 9	44	44	Av.
tsfoot	50	58	− 8	47	*57*	− 10	57	61	− 4	54	68	− 14
od Anemone	79	85	− 6	65	*81*	− 16	75	84	− 9	77	88	− 11
ckthorn	84	92	− 8	77	*93*	− 16	89	98	− 9	93	102	− 9
lic Hedge Mustard	102	104	− 2	103	*106*	− 3	104	111	− 7	107	113	− 6
rse-chestnut	117	118	− 1	111	*117*	− 6	124	123	+ 1	129	127	+ 2
wthorn	127	126	+ 1	123	*123*	Av.	129	127	+ 2	133	130	+ 3
ite Ox Eye	146	142	+ 4	147	*137*	+ 10	141	139	+ 2	147	145	+ 2
g Rose	150	151	− 1	155	*148*	+ 7	155	154	+ 1	158	157	+ 1
ck Knapweed	175	170	+ 5	176	*168*	+ 8	175	167	+ 8	176	174	+ 2
rebell	188	186	+ 2	191	*177*	+ 14	185	179	+ 6	187	188	− 1
ater Bindweed	178	181	− 3	186	*179*	+ 7	183	185	− 2	194	188	+ 6
	260	264	− 4	249	*263*	− 14	265	268	− 3	266	270	− 4
an for the 13 Plants	130	132	− 2	128	*130*	− 2	132	134	− 2	136	138	− 2

PLANTS.	E England, E.			F England, N.W.			G Ireland, N.			H Scotland, W.		
tel	36	40	− 4	36	46	− 10	46	52	− 6	50	50	Av.
tsfoot	54	61	− 7	53	67	− 14	62	74	− 12	74	82	− 8
od Anemone	81	87	− 6	94	93	+ 1	78	85	− 7	103	102	+ 1
ckthorn	88	99	− 11	105	104	+ 1	91	100	− 9	113	110	+ 3
lic Hedge Mustard	107	109	− 2	127	123	+ 4	122	*117*	+ 5	113	*123*	− 10
se-chestnut	124	122	+ 2	131	126	+ 5	134	127	+ 7	144	135	+ 9
wthorn	129	127	+ 2	138	134	+ 4	142	134	+ 8	142	143	− 1
ite Ox Eye	144	143	+ 1	150	148	+ 2	162	151	+ 11	161	*154*	+ 7
Rose	155	153	+ 2	160	157	+ 3	168	161	+ 7	169	163	+ 6
k Knapweed	171	177	− 6	192	181	+ 11	202	202	Av.	203	*185*	+ 18
ebell	182	*183*	− 1	185	180	+ 5	...	*188*	...	179	*194*	− 15
ater Bindweed	185	187	− 2	188	186	+ 2	190	*190*	Av.	...	*196*	...
	262	261	+ 1	282	280	+ 2	278	*274*	+ 4	...	*280*	...
an for the 13 Plants	132	134	− 2	142	140	+ 2	140*	139*	+ 1*	132†	131†	+ 1†

PLANTS.	I England, N.E.			J Scotland, E.			K Scotland, N.			British Isles.		
el	42	53	− 11	55	*52*	+ 3	45	*49*	− 4	41	46	− 5
tsfoot	55	70	− 15	65	*73*	− 8	53	*70*	− 17	57	67	− 10
od Anemone	88	96	− 8	84	*97*	− 13	93	*94*	− 1	83	90	− 7
ckthorn	108	110	− 2	119	*109*	+ 10	104	*106*	− 2	97	102	− 5
lic Hedge Mustard	123	*121*	+ 2	136	*122*	+ 14	...	*118*	...	114	*115*	− 1
se-chestnut	142	138	+ 4	149	*133*	+ 16	151	*130*	+ 21	132	127	+ 5
wthorn	146	140	+ 6	156	*139*	+ 17	153	*136*	+ 17	138	133	+ 5
ite Ox Eye	155	158	− 3	170	*153*	+ 17	169	*150*	+ 19	154	147	+ 7
Rose	167	167	Av.	174	*164*	+ 10	168	*161*	+ 7	162	158	+ 4
k Knapweed	197	198	− 1	199	*184*	+ 15	208	*181*	+ 27	189	181	+ 8
ebell	188	188	Av.	195	*193*	+ 2	203	*190*	+ 13	188	*186*	+ 2
ater Bindweed	193	*194*	− 1	201	*195*	+ 6	211	*192*	+ 19	191	*188*	+ 3
	280	*278*	+ 2	285	*279*	+ 6	294	*276*	+ 18	272	*272*	Av.
an for the 13 Plants	145	147	− 2	153	*146*	+ 7	154*	145*	+ 9*	140	139	+ 1

* For 12 Plants. † For 11 Plants.

\+ indicates the number of days later than the average date.

− ,, ,, ,, earlier ,, ,,

Av. ,, average date (1891-96).

The dates in *italics* are approximate averages.

MARCH.—*Barnstaple* (A)—1st. Vegetation unusually forward. *Sidcot* (A)—2nd and 3rd. Fierce gales. Many trees, especially elm and apple trees, were blown down. *Bassaleg* (A)—25th. The village sycamore in full leaf. *Bembridge* (C)—3rd. A fearful gale swept over the island, which uprooted a very large number of fine elms and other trees; over a hundred were blown down within a mile of Bembridge Church. *Blandford* (C)—29th. Chiffchaff first heard. *Bexhill* (C)—Farm land too wet to work until the end of the month. *Churt* (C)—22nd. Chiffchaff first heard. *Cheltenham* (D)—26th. Chiffchaff first heard. *Leominster* (D)—24th. Chiffchaff first heard. *Hodsock* (D)—22nd. Thrush's nest with eggs. *Ashwell* (E)—21st. Found song-thrush's nest with eggs in it. *Newmill* (J)—11th. Frog spawn first seen.

APRIL.—*Mawnan* (A)—9th. Chiffchaff first heard. *Falmouth* (A)—13th. Humming bird hawk moth first seen. *Long Ashton* (A)—Cuckoos very numerous. *Bassaleg* (A)—5th. The blossoms of pears, plums, and early apples spoiled by sharp frost. *St. Arvans* (A)—8th. Chiffchaff first heard. *Killarney* (A)—24th. A great deal of blight on apple trees, the flowers have never opened, the buds apparently killed. *Bembridge* (C)—Some early potatoes were dug out of doors at the end of the month. *Buckhorn Weston* (C)—1st. A snowstorm and a swallow. *Chislehurst* (C)—4th. Chiffchaff heard. *Churt Vicarage* (C)—Nightingales again numerous this year. 7th. Wryneck first heard. *Churt* (C)—Flocks of larks on the uplands, a most unusual sight at this time of year. *Watford* (D)—15th. Pears and plums very full of bloom. *Berkhamsted* (D)—A remarkable quantity of violets and dandelions this spring. The leaves on the blackthorn appeared before the flowers, which were scanty. *Ross* (D)—19th. Chiffchaff first heard. *Tacolneston* (E)—16th. Wryneck first heard. *Ambleside* (F)—21st. Corncrake first heard. *Edgeworthstown* (G)—2nd. Heard chiffchaff. *Loughbrickland* (G)—1st. Chiffchaff first heard. 22nd. Landrail first heard. *Antrim* (G)—4th. Chiffchaff first heard.

MAY.—*Marazion* (A)—3rd. Swifts first seen. *Mawnan* (A)—10th. Swifts first seen. *Sidcot* (A)—Pear and apple blossoms which promised so well were to a large extent destroyed by cold, dry winds. *St. Arvans* (A)—9th. Swifts first seen. *Bembridge* (C)—13th. Potatoes injured by frost. *Muntham* (C)—More queen wasps observed this spring than I have ever known before. *Chislehurst* (C)—13th. Potatoes and bracken blackened. 17th. Swifts first seen. *Churt Vicarage* (C)—13th. Potatoes practically destroyed by frost. The abundant bloom on pear and apple trees much injured by cold winds and frost. 17th. May-fly first seen, and first swarm of bees. *Churt* (C)—Both tree and bush fruits severely damaged by frost during the first fortnight. *Chiddingfold* (C)—Butterflies remarkably scarce. 13th. Much damage done to the blossom of the oak and ash, also to strawberries and vegetables, by frost. *Cheltenham* (D)—The cold winds and sharp occasional frosts damaged the prospects of the fruit crops severely. *Watford* (D)—11th and 12th. Potatoes cut by frost. *St. Albans* (D)—12th. A pond was covered with ice the thickness of a penny. *Berkhamsted* (D)—Very few flowers, as a rule, on the hawthorn; in fact many bushes had none at all. *Ross* (D)—The date for flycatcher, the earliest for 11 years. *Leominster* (D)—No oak apples this year. *Evesham* (D)—4th. Swift first seen *Northampton* (D)—The cold North-east winds, together with the hot sun, burnt up and caked the surface of the ground to a remarkable degree for the time of year. *Macclesfield* (D)—Several sharp frosts in the early part of the month did much damage to fruit blossom, especially plums, currants, and gooseberries. Horse-chestnut trees in exposed situations were scorched, and the flower buds killed. *Lexden* (E)—8th. Swifts first seen. *Tacolneston* (E)—17th. First swarm of bees. *Conway* (F)—1st. Swift first seen. 2nd. Corncrake first heard. *Cronkbourne* (F)—Hawthorn flowers unusually scarce. *Piperstown* (G)—Very few cuckoos, corncrakes, or butterflies this year. No uncommon butterflies, and

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1897.

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
A											
Marazion	8	84	114	...	...	307	77	103	80	143	192
Mawnan	3	110	121	...	...	...	...	123	108	129	169
Falmouth	...	85	...	...	...	301	52	118	138	141	...
Liskeard	2	82	108	...	...	312	45	72	72	117	...
Altarnon	36	105	111	...	106	...	10	74	117	121	*118*
Tiverton	...	107	116	...	...	...	54	...	112	...	...
Westward Ho	2	112	109	...	*172*	266	84	116	116	136	...
Sidcot	...	100	100	115	128	...	71	...	...	...	...
Long Ashton	...	99	110	...	...	258	35	52	95	118	...
Clifton	...	...	106	...	...	...	...	41	129	129	...
Penarth	...	...	...	...	...	...	*135*	126	108	135	160
Cardiff	...	106	...	...	...	...	...	95	...	...	...
Castleton	34	92	105	...	121	289	38	45	114	116	151
Bridgend	41	104	...	...	...	...	109	105	...	...	...
Bassaleg	38	104	111	115	127	283	38	82	'95	97	128
St. Arvans	39	106	104	118	140	276	45	76	118	118	...
St. Davids	...	85	106	...	...	256	96	...	121	*154*	176
Aberystwith	10	108	117	...	134	272	...	115	98	138	166
B											
Cork	...	115	122	...	...	...	108	133	129	109	171
Killarney	10	106	117	...	...	262	65	84	113	113	138
Ferns	2	100	106	...	...	283	91	102	117	117	124
Glendalough	...	99	113	...	132	271	60	...	137	138	...
Geashill	...	105	116	...	124	...	46	48	136	129	176
C											
Bembridge	10	86	103	94	...	320	51	48	...	143	...
Blandford	40	86	103	107	96	...	47	82	87	98	163
Buckhorn Weston	2	91	105	115	...	279	33	123	89	89	171
Havant	37	91	109	111	124	304	...	47	89	121	170
Bexhill-on-Sea	2	103	98	111	130	310	61	79	119	130	152
Muntham	5	104	103	108	122	312	66	97	93	104	...
Dover	...	109	...	...	...	295	...	...	...	...	...
Swanley	...	...	105	...	...	...	...	97	118	...	...
Chislehurst	3	109	109	108	129	289	51	82	137	139	...
Coneyhurst	45	105	97	107	130	284	49	82	83	...	...
Churt Vicarage	10	97	107	111	107	274	48	93	116	123	165
Churt	2	105	105	110	125	...	41	52	73	116	161
Chiddingfold	...	108	98	96	...	280	38	55	108	117	150
Winterfold	45	...	101	108	...	293	45	57	...	...	...
Oxshott	41	100	105	108	...	...	...	...	...	...	...
East Molesey	6	110	116	120	...	...	45	49	118	...	...
Marlborough	11	108	109	...	147	...	...	...	120	113	173
D											
Oxford	...	...	115	...	...	...	...	...	...	...	...
Cheltenham	...	104	108	115	141	274	49	80	117	...	178
Beckford	35	105	105	108	143	283	35	123	110	129	141
Watford	...	117	109	119	146	277	...	...	123	...	...
St. Albans (The Grange)	...	114	114	113	...	...	48	...	124	141	...
St. Albans (Addisc'be Lodge)	40	*132*	116	109	...	...	51	100	...	...	...

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1897—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
St. Albans (Worley Road)	3	104	108	106	...	...	...	...	...	...	...
Radlett	...	107	110	...	...	...	45	98	...	...	...
Berkhamsted	2	93	109	114	...	...	41	93	109	138	139
Harpenden	39	114	109	121	...	281	41	81	114	137	...
Ross	5	104	106	...	129	...	49	69	100	121	...
Leominster	42	87	110	110	141	277	38	131	116	116	...
Evesham	34	86	104	109	...	...	40	66	105	117	...
Ullenhall	37	87	109	105	137	285	45	69	98	...	120
Churchstoke	44	109	104	...	138	...	74	103	136	121	181
Thurcaston	...	89	...	...	...	...	...	101	136	136	...
Beeston	...	103	117	...	...	278	79	100	117	...	...
Hodsock	11	90	115	109	...	291	40	118	131	139	...
Macclesfield	45	117	117	...	...	277	...	135	148	...	...
Belton	40	104	114	117	126	319	40	...	...	119	...
E											
Wormley	...	...	...	...	...	...	52	...	...	...	...
Hitchin	...	...	110	105	...	...	51	...	...	136	171
Ashwell	...	108	110	108	122	310	...	...	...	...	...
Bocking	...	115	113	114	...	...	...	...	...	...	...
Lexden	13	105	109	105	145	283	53	52	109	124	163
Sproughton	1	110	115	109	140	295	41	123	116	134	...
Tacolneston	...	104	108	110	...	...	41	...	...	124	...
Brundall	...	...	115	109	...	...	...	...	...	...	...
F											
Ellesmere	37	...	...	...	...	...	40	...	...	...	...
Palé	38	86	111	...	128	298	51	113	117	136	192
Conway	2	109	113	...	...	300	69	72	...	...	...
Claughton	1	108	104	...	...	...	98	100	...	...	...
Ambleside	10	110	121	...	148	264	82	124	138	141	141
Cronkbourne	79	121	135	...	...	285	40	...	136	...	...
Orry's Dale	1	115	116	...	...	...	46	127	114	...	...
Sulby	5	106	108	...	132	293	80	109	108	...	161
G											
Ardgillan	37	108	132	...	...	...	...	41	134	136	162
Piperstown	4	108	117	...	...	276	46	46	108	113	134
Edgeworthstown	...	109	114	...	143	272	114	...	113	140	...
Westport	33	103	115	...	...	270	48	*237*	...	...	...
Loughbrickland	42	110	130	...	...	282	...	26	129	140	...
Saintfield	38	110	118	...	...	284	...	...	136	139	...
Antrim	36	95	120	...	124	290	45	...	135	139	...
Hazelbank	42	...	118	...	...	...	...	141	...	138	192
Ballynagard	...	109	116	...	...	...	...	...	...	...	...
Ramelton	36	100	115	...	138	275	46	139	136	129	...
H											
New Galloway	45	112	115	...	...	303	41	...	133	...	...
Thornhill	...	117	...	...	...	...	53	110	...	...	...
Jardington	41	116	115	...	118	...	...	117	133	...	189
Helensburgh	1	108	113	...	...	...	...	108	137	...	...

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1897—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange-Tip Butterfly.	Meadow Brown Butterfly.
I											
Claxby	...	109	111	...	...	...	112	...	124	142	...
Great Cotes	39	104	118	117	135	292	50	...	...	...	...
Thirsk	...	101	122	...	143	300	52	110	84	136	182
East Layton	...	113	...	...	148	...	...	84	153	155	...
Durham	40	117	124	...	...	277	80	113	136	...	...
Corbridge-on-Tyne	38	105	118	...	...	259	...	122	...	...	...
Cambois	38	110	114	...	*157*	281	...	106	...	...	...
J											
Kirriemuir	...	112	137	...	...	279	...	...	...	...	...
Aberdeen	36	118	137	...	131	*237*	83	...	151	...	...
Newmill	60	117	118	...	...	263	50	49	134	135	176
K											
Invermoidart	...	...	116	...	...	...	...	112	125	...	*108*
Roshven	...	111	...	...	...	...	...	...	...	...	...
Beauly	66	132	118	...	...	271	68	...	141	113	...
Inverbroom	...	*147*	134	...	...	...	47	...	...	...	...
Dingwall	47	119	134	...	...	260	52	139	141	...	...
Watten	...	135	140	...	...	...	136	...	136	...	177
Mean Dates for the British Isles in 1897	25 Jan. 25th.	105 Apl. 15th	113 Apl. 23rd	110 Apl. 20th	131 May 11th	284 Oct. 11th	57 Feb. 26th	92 Apl. 2nd	117 Apl. 27th	127 May 7th	163 June 12th
Mean Dates for 1891-97	Feb. 1st.	Apl. 16th	Apl. 21st	Apl. 21st.	May 13th	Oct. 13th	Feb. 27th	Apl. 6th	Apl. 14th	May 5th	June 8th

The dates in *italics* have not been taken into consideration when calculating the means for the British Isles.

the common ones not nearly so numerous as usual. *Edgeworthstown* (G)—12th. Swift first seen. *Westport* (G)—8th. Swift first seen. *Antrim* (G)—4th. Corncrake first heard. *Jardington* (H)—A very barren month; pastures bare throughout it. *Durham* (I)—21st. Swift first seen. *Inverbroom* (K)—13th. A shoal of about 300 whales came into Loch Broom in the evening, remained that night, and departed the next morning about mid-day. *Dingwall* (K)—Fruit blossom ruined by frost and high winds.

June.—*Mawnan* (A)—7th. Hay-cutting began. *Barnstaple* (A)—1st. The observation of a large number of private test plants shows that the season is about 10 days later than that of 1896. *Killarney* (B)—Slugs and snails numerous. 13th. Peas and new potatoes ready for eating. *Cheltenham* (D)—Butterflies scarce. *Beckford* (D)—17th. Haymaking general. *Harpenden* (D)—14th. First wheat ear observed out of sheath. *Palé* (F)—Dog roses exceptionally beautiful; the hedges appeared one mass of bloom. The hawthorn, on the other hand, made but a poor show this year. *Ardgillan* (G)—14th. Hawthorn blossom still out, and fading only in sheltered places. *Kirriemuir* (J)—Have not seen a wasp of any kind this season. *Newmill* (J)—Butterflies scarce.

TABLE VI.—Estimated Yield of Farm Crops in 1897.

Description of Crop.	England.						Scotland.			Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H W.	J E.	K N.	B and G S. and N.	
Wheat	Av.	U. Av.	U. Av.	U. Av.	Av.	U. Av.	Av.	Av.	Av.	Av.	U. Av.
Barley	Av.	Av.	Av.	Av.	Av.	U. Av.	Av.	Av.	Av.	Av.	Av.
Oats	Av.	Av.	U. Av.	U. Av.	O. Av.	U. Av.	O. Av.	U. Av.	U. Av.	O. Av.	Av.
Corn Harvest began, average Date	213 (Aug. 1)	210 (July 29)	217 (Aug. 5)	217 (Aug. 5)	229 (Aug. 17)	232 (Aug. 20)	253 (Sept. 10)	247 (Sept. 4)	244 (Sept. 1)	232 (Aug. 20)	229 (Aug. 17)
Beans	Av.	Av.	Av.	Av.	Av.	Av.	Av.	U. Av.	...	...	Av.
Peas	O. Av.	O. Av.	O. Av.	Av.	Av.	Av.	...	U. Av.	...	...	O. Av.
Potatoes	Av.	Av.	Av.	U. Av.	Av.	Av.	U. Av.	U. Av.	Av.	Av.*	Av.
Turnips	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.	Av.
Mangolds	O. Av.	O. Av.	O. Av.	Av.	O. Av.	Av.	Av.	...	...	Av.	O. Av.
Hay (Permanent Pastures)	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	O. Av.	O. Av.	Much U. Av.	Much U. Av.	Much O. Av.	Much O. Av.
Hay (Clover, etc.)	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	Much O. Av.	O. Av.	O. Av.	Much U. Av.	Much U. Av.	Much O. Av.	Much O. Av.

The variations from the average for the above crops have been obtained from the returns which appeared in the *Agricultural Gazette*, July 26, 1897.

* After the returns had been sent in the potatoes in Ireland were attacked by disease, which reduced the crop to one much under average.

TABLE VII.—Estimated Yield of Fruit Crops in 1897.

Description of Crop.	England.						Scotland.	Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H, J, and K W. E. and N.	B and G S. and N.	
Apples	Much U. Av.	Much U. Av.	U. Av.	Much U. Av.	U. Av.	Much U. Av.	U. Av.	Much U. Av.	U. Av.
Pears	Much U. Av.	Much U. Av.	U. Av.	U. Av.	U. Av.	Much U. Av.	U. Av.	Much U. Av.	U. Av.
Plums	Much U. Av.	Much U. Av.	Much U. Av.	Much U. Av.	Much U. Av.	Much U. Av.	U. Av.	Much U. Av.	Much U. Av.

TABLE VIII.—Approximate Variations from the Average in Mean Temperature, Rainfall, and Sunshine, 1896-97.

Winter 1896-97.

Temperature.

Months.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
December	−0·8	−1·2	−0·2	−0·6	+0·2	−0·4	−1·0	−0·4	0·0	+0·2	+0·4
January	−3·3	−4·0	−2·8	−3·5	−3·3	−3·5	−3·5	−3·5	−3·0	−3·0	−3·5
February	+3·5	+3·0	+3·0	+3·0	+2·5	+2·0	+2·5	+1·3	+2·3	+1·3	+0·3
Winter	−0·2	−0·7	0·0	−0·4	−0·2	−0·6	−0·7	−0·9	−0·2	−0·5	−0·9

Rain.

	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
December	+2·6	+1·8	+0·8	+0·7	+0·7	+0·9	+0·2	+0·1	+1·1	+1·3	−1·3
January	−1·3	−1·3	−0·6	−0·2	+0·1	−1·4	−1·5	−3·2	+0·2	−0·9	−3·1
February	+1·7	−0·1	+0·9	+0·8	+0·6	+0·2	−0·2	−0·9	−0·1	−1·2	−0·8
Winter	+3·0	+0·4	+1·1	+1·3	+1·4	−0·3	−1·5	−4·0	+1·2	−0·8	−5·2

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
December	+ 6	+ 9	− 1	+ 3	+ 3	−16	+19	+ 2	+ 7	− 9	+ 6
January	+ 5	+23	− 3	− 5	−11	+ 3	+19	+21	− 1	− 6	+11
February	−25	−25	−20	−17	−15	−25	−17	−20	− 4	− 1	− 7
Winter	−14	+ 7	−24	−19	−23	−38	+21	+ 3	+ 2	−16	+10

Spring 1897.

Temperature.

	°	°	°	°	°	°	°	°	°	°	°
March	+1·2	0·0	+2·2	+1·8	+2·0	+0·8	−0·4	+0·2	+0·8	−0·2	−0·2
April	−0·3	−1·0	0·0	−1·0	−0·8	−1·8	−2·3	−1·8	−1·0	−2·0	−1·5
May	−1·0	−1·0	−1·0	−1·8	−2·0	−2·0	−1·3	−2·0	−2·5	−2·8	−2·5
Spring	0·0	−0·7	+0·4	−0·3	−0·3	−1·0	−1·3	−1·2	−0·9	−1·7	−1·4

Rain.

	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
March	+2·9	+3·1	+2·1	+1·4	+0·9	+1·3	+2·2	+2·0	+0·8	+1·6	+1·1
April	+1·7	+1·5	−0·1	+0·5	+0·1	+1·2	+1·3	+0·5	−0·2	0·0	+0·1
May	−0·6	−1·0	−1·0	−1·1	−1·0	−0·5	−0·3	−0·5	−0·8	−0·3	+0·3
Spring	+4·0	+3·6	+1·0	+0·8	0·0	+2·0	+3·2	+2·0	−0·2	+1·3	+1·5

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
March	−18	− 7	− 1	+ 6	+ 2	− 2	0	−14	− 7	−28	−12
April	−30	−24	+ 6	+11	+ 4	+20	0	+ 9	+19	+18	+33
May	+31	+31	+37	+54	+39	+74	+42	+49	+46	+31	+42
Spring	−17	0	+42	+71	+45	+92	+42	+44	+58	+21	+63

\+ indicates above the average, − below it.

TABLE VIII.—VARIATIONS FROM THE AVERAGE—*Continued.*

SUMMER 1897.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
June . .	+2·4	+1·0	+2·8	+2·2	+2·0	+1·0	−0·2	+0·6	+0·6	−0·4	−0·4
July . .	+2·3	+2·0	+2·3	+1·3	+0·5	+1·0	+1·8	+1·3	−0·3	+0·8	+1·8
August . .	+1·0	+1·0	+2·0	+1·8	+2·3	+1·8	+0·8	+2·5	+2·8	+2·3	+3·0
Summer . .	+1·9	+1·3	+2·4	+1·8	+1·6	+1·3	+0·8	+1·5	+1·0	+0·9	+1·5

Rain.

	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
June . .	+0·2	+1·7	+0·6	+0·6	0·0	+1·2	+2·7	+1·7	+0·4	+1·7	−0·6
July . .	−1·4	−0·8	−1·6	−1·4	−1·9	−1·6	−0·5	−1·0	−1·3	−1·3	−0·5
August . .	+1·0	+1·5	+0·2	+0·2	+0·1	+0·7	+0·7	+0·1	+0·2	+0·8	−0·6
Summer . .	−0·2	+2·4	−0·8	−0·6	−1·8	+0·3	+2·9	+0·8	−0·7	+1·2	−1·7

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
June . .	+12	−72	−17	−15	−21	−48	−79	−68	−22	−49	−6
July . .	+21	+15	+59	+74	+61	+52	+29	+36	+77	+77	+54
August . .	+27	+16	+17	+38	+35	+27	+28	+23	+59	+32	+26
Summer . .	+60	−41	+59	+97	+75	+31	−22	−9	+114	+60	+74

AUTUMN 1897.

Temperature.

	°	°	°	°	°	°	°	°	°	°	°
September .	−1·4	−1·2	−1·2	−1·4	−1·6	−1·8	−1·0	−1·4	−1·6	−1·0	−0·8
October . .	+3·0	+3·0	+3·0	+1·0	+1·0	+2·0	+2·8	+2·5	+1·5	+1·5	+2·0
November .	+3·0	+3·8	+3·0	+2·5	+1·8	+3·5	+4·3	+5·0	+3·8	+4·5	+3·0
Autumn . .	+1·5	+1·9	+1·6	+0·7	+0·4	+1·2	+2·0	+2·0	+1·2	+1·7	+1·4

Rain.

	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
September .	+1·6	+0·3	+0·1	+0·5	+1·0	+0·5	−0·3	+0·3	+0·8	−1·1	+1·1
October . .	−2·8	+0·3	−2·8	−1·6	−2·0	−2·1	−1·0	−2·3	−1·4	−0·9	−1·2
November .	−1·6	+1·3	−2·0	−1·4	−1·7	−0·5	−1·3	−0·9	−1·1	−1·4	−1·1
Autumn . .	−2·8	+1·9	−4·7	−2·5	−2·7	−2·1	−2·6	−2·9	−1·7	−3·4	−1·2

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
September .	−12	+14	−18	−8	−12	+9	+20	0	−1	+3	+17
October . .	−8	+13	+26	+16	+19	+17	−9	+7	+14	+21	+26
November .	−25	−2	−16	−24	−23	−2	−15	−22	−28	−20	−2
Autumn . .	−45	+25	−8	−16	−16	+24	−4	−15	−15	+4	+41

The above Table has been compiled from the variations from the mean given in the *Weekly Weather Reports* issued by the Meteorological Office.

Daisies flowering thickly on old grass; in some cases the fields at a short distance looked as if covered with snow.

JULY.—*Mawnan* (A)—24th. Harvest began. *Glendalough* (B)—Weevils, rose-beetles, and earwigs were dreadful pests during June and July, but there was an unusual absence of caterpillars, greenfly, and wasps. Ladybirds numerous. *Coneyhurst* (C)—10th. Cuckoo last heard. *Churt Vicarage* (C)—On this light soil plants have suffered much from drought and excessive heat. *Churt* (C)—1st. Cuckoo last heard. *Beckford* (D)—26th. Wheat harvest began. *Berkhamsted* (D)—One of the best rose seasons I have ever known. *Hodsock* (D)—30th. Harvest began. *Bocking* (E)—30th. Harvest began. *Orry's Dale* (F)—2nd. Cuckoo last heard—a remarkably late date for the Isle of Man. *Newmill* (J)—Wasps very scarce. *Invermoidart* (K)—Butterflies very scarce this year. *Watten* (K)—15th. Meadow-brown butterflies, hitherto rare, are now plentiful.

AUGUST.—*Mawnan* (A)—Very few wasps this summer. *Long Ashton* (A)—Larger crops of blackberries than for some years. *St. Arvans* (A)—Earwigs very numerous. *Killarney* (B)—Wasps very scarce. Much hay ruined by rain. *Glendalough* (B)—The weather was so wet and sunless that late sown peas ripened none of their pods at their proper season, but made fresh growth and yielded a good quantity of first-rate peas late in October. *Geashill* (B)—The growth of weeds on the lawn and about the garden quite abnormal this summer; the common dock measured 5 ft. 7 ins. But few earwigs or wasps. *Churt* (C)—Wasps and butterflies of all kinds have been scarce. *Chiddingfold* (C)—During all three summer months house-flies have been very numerous and troublesome. *Cheltenham* (D)—White butterflies became very abundant. Wasps very scarce. *Ross* (D)—28th. Swift last seen. *Hodsock* (D)—The long drought came to an end about August 24, previous to which the lawns were quite brown. *Palé* (F)—Mushrooms plentiful in the pastures. Wasps very scarce. *Cronkbourne* (F)—No wasps seen since the queen wasps in the spring until the 12th, when one was observed. *Westport* (G)—A great scarcity of wasps this year. *Jardington* (H)—A remarkable absence of wasps this summer. 7th. Harvest began. *Cambois* (I)—20th. Harvest began. *Newmill* (J)—White butterflies are now very plentiful. 21st. Harvest began. *Invermoidart* (K)—Wasps very scarce. 23rd. Harvest began.

SEPTEMBER.—*Barnstaple* (A)—1st. The profusion of flowers and the fresh verdure of vegetation are due chiefly to the abundant August rainfall. *Long Ashton* (A)—Swallows left early. *Harpenden* (D)—An enormous quantity of hazel nuts; other wild fruits comparatively scarce. There are but few sloes, and not many hawthorn or holly berries. *Leominster* (D)—Not an acorn anywhere, although we are crowded with oak trees, and no beech nuts. *Lexden* (E)—1st. Harvest completed. *Palé* (F)—10th. French beans and vegetable marrows destroyed by frost. There has not been such a frost here so early for over 20 years. *Great Cotes* (I)—27th. The immigration of the song-thrush on the east coast has commenced, and very considerable numbers have arrived. *Dingwall* (K)—2nd. A sharp frost destroyed foliage of vegetable marrows, etc.

OCTOBER.—*Aberystwith* (A)—Painted lady butterfly seen. *Chislehurst* (C)—Swallows and martins left early this year. *Churt Vicarage* (C)—Swallows have left 10 days earlier than usual. Wasps have been scarce this autumn. 7th. Dahlias destroyed by frost. *Churt* (C)—Holly berries and haws abundant, acorns scarce. *Cheltenham* (D)—Swallows left early. *Beckford* (D)—13th. Dahlias and kidney beans cut down by frost. *Watford* (D)—6th. Dahlias killed. *Hodsock* (D)—7th. Dahlias blackened by frost. *Macclesfield* (D)—The finest October I remember; roses, dahlias, and many other flowers were blooming the whole month. The autumn tints on beeches, horse-chestnuts, oaks, etc., were marvellously beautiful. *Hitchin* (E)—Holly and hawthorn berries

abundant. *Palé* (F)—The trees ripened their foliage to perfection, the exquisitely coloured leaves could scarcely have been surpassed. *Ambleside* (F)—10th. The horse-chestnuts are still quite green, and only here and there the under leaves have turned yellow. *Durham* (I)—14th. Dahlias cut down by frost.

NOVEMBER.—*Mawnan* (A)—30th. A Glastonbury holy thorn already in blossom. *Falmouth* (A)—14th. Martins last seen. *Tiverton* (A)—Until the hailstorms of the 28th-30th wild flowers were plentiful here. *Barnstaple* (A)—25th. Found 55 species of wild flowers in bloom, the usual number for the same time of year being about 12. *Bassaleg* (A)—9th. Geraniums, etc., still in bloom, and spring flowering bulbs an inch above ground. *Geashill* (B)—14th. Dahlias killed. *Bembridge* (C)—Picked green peas from seed ripened in the previous June and sown directly. Ripe strawberries and French beans were to be had until the 28th. Dahlias and nasturtiums in flower throughout the month. *Buckhorn Weston* (C)—During the month we picked 100 kinds of wild flowers, including white violets, and dog's mercury. *Havant* (C)—17th. Last martin seen. *Churt Vicarage* (C)—6th. Oak and elm trees still full of foliage, and many with leaves still green. *Winterfold* (C)—14th. Dahlias cut down by frost. *East Molesey* (C)—21st. Leaves still on the elms. *Cheltenham* (D)—During the last week of the month several oaks were seen full of foliage. *Watford* (D)—Beautiful autumn tints, but lasting a short time. 20th. Trees almost leafless. *Berkhamsted* (D)—19th. Dahlias cut down, or 18 days later than the average date of their destruction in the past 12 years. *Macclesfield* (D)—Many trees retained their leaves well into November. *Lexden* (E)—26th. Nasturtiums killed by frost. *Ambleside* (F)—30th. Many flowers still out in the cottage gardens, including roses, geraniums, etc. *Cronkbourne* (F)—16th. Dahlias killed by frost. *Currygrane* (G)—28th. Primrose in bloom in hedgerows. *Antrim* (G)—Clematises, marigolds, and other plants flowering freely at the end of the month. *Ramelton* (G)—Many flowers out in the garden until the end of the month. *Cambois* (I)—Some small leaves to be seen on elder during this month. *Aberdeen* (J)—16th. Dahlias cut down by frost. *Newmill* (J)—Roses in bloom, also raspberries and strawberries, in a few instances, during a great part of the month. Autumn tints very brilliant. *Watten* (K)—A very mild autumn, so that flowers continued to bloom and the grass kept green far on in December.

Errata in Report for 1896.

In Table V., District D, Beeston, the day of year "134" given for *Nightingale* should refer to *Flycatcher*.

In Table V., District G, Antrim, the day of year "137" given for *Nightingale* should refer to *Flycatcher*.

DISCUSSION.

The President (Mr. F. C. BAYARD) said that he should like to have seen some reference to the past year as compared with the Jubilee year of ten years ago, 1887, which was of a similar character. He was pleased to see the diagram illustrating the appearance and flight of migratory birds, and hoped that Mr. Mawley might be able in future reports to present in a diagrammatic form the dates of the appearance of insects, which in many respects gave more information, phenologically, than the movements of birds.

Mr. A. CHANDLER, in a letter to Mr. Marriott, said: "As promised, I send you

a box containing the phenological curiosity of this wonderfully mild winter, a piece of blackberry in bloom, *Rubus vulgaris*. It was a mass of white bloom from about the third week in January. It was growing (blooming) on the east side of the Chapel Hill Meteorological Observatory, Torquay, nearly 300 feet above sea-level, from a very strong stool, the main stem of which is about an inch in diameter. I hope it will be of use at your meeting to-morrow, when Mr Mawley reads his Phenological Report. The bloom is over and the fruit is setting. I have secured what remained when I cut it last week with a little florist's gum."

Mr. J. SMYTH corroborated the statement in the report as to the marked scarcity of wasps, but remarked on the extraordinary number of *Agrotis exclamatimis* caterpillars which manifested themselves in the north of Ireland, with disastrous results to the linen-bleaching industry. From a correspondence with Miss Ormerod the entomologist, he found that a similar plague occurred eight years ago. The caterpillars were most tenacious of life, the only effective way of killing them being by boiling them with the linen.

Mr. R. H. CURTIS said with reference to the heavy storm which occurred early in March, to which Mr. Mawley had referred as doing so much damage to vegetation in the west of England, that it was in some respects a gale of quite exceptional severity. At the Society's last Exhibition Mr. C. E. Peek showed the anemogram which he had obtained in this gale from the pressure-tube anemometer at his observatory at Rousdon, close to the borders of Devon and Dorset. This showed that a maximum velocity of 100 miles per hour had been recorded between 8 a.m. and 9 a.m. on the morning of March 3 ; and this velocity is equal to a pressure of 30 lbs. upon the square foot ; up to the present time it was by far the highest record which had been obtained with the pressure-tube anemometer since its introduction. At Scilly, in the same gale, the force, though very severe, was not quite so violent, the maximum velocity reached being 84 miles per hour, equal to a pressure of 21 lbs. per square foot. Happening to be himself in Cornwall at the time of the gale, he could testify to its exceptional character there, whilst in passing through Devon and Somerset a few days later he had witnessed on every hand abundant evidence of its violence in those counties, in the shape of damaged buildings and prostrate trees. Apparently it was most destructive in and near the valley of the Exe, and from thence eastward over Dorset and the southern portions of Somerset and Wilts.

Mr. G. J. SYMONS said that the damage wrought by the storm of March was very great in and around Salisbury. Two places near that one illustrated by Mr. Mawley's slide (Northlands, Salisbury) suffered terribly. At Wilton House there was great destruction of trees, quite two-thirds being either uprooted or broken. The storm seemed to have died out about Alton, Hants. He thought that accounts of both the Essex storm (June 24) and that of Ash Wednesday (March 3, 1897) should have been brought before the Society. He was under the impression that the strawberry crop of last year was a very poor one, and not abundant as stated in the report.

Mr. W. MARRIOTT said that when inspecting the Society's stations in the summer he had passed through the district affected by the storm of March 3, and he was much struck by the number of trees then down, although nearly six months after the storm. The neighbourhood of Crediton, Devon, appeared to have suffered the most severely, for he counted 16 or 18 trees uprooted in one field. The eastern limit of this storm seemed to be about Winchester. The storm that wrought such damage to the crops in Essex on June 24 was of the tornado type, the width not exceeding two miles. The hail was locally supposed to be the great feature of this storm, but in his (Mr. Marriott's) opinion it was the wind. Numbers of trees were snapped off owing to the sudden blast of the wind. The hail was remarkable for size, many hailstones being 5 and 6 ins. in

circumference, and very similar to those that fell at Richmond, Yorks, on July 8, 1893. The hailstones showed several coatings of white and clear ice. The damage done by the hail was immense, especially to glass-houses; and buildings were partly demolished by the violence of the wind.

Mr. J. HOPKINSON said that the only part of Hertfordshire seriously affected by the storm, which was so disastrous to the crops in the adjacent county of Essex, was the district between Luton and Hitchin, where trees were blown down and great damage was done to crops. Nearly all the windows of several houses were smashed by the hailstones. With regard to the statement made by Mr. Mawley in the report that his strawberry crop was above the average, his own was far below it, in fact one of the worst he had known. This was the more remarkable as the distance between his residence and Mr. Mawley's was inconsiderable. With regard to the lack of observers in some districts, he thought that if application were made to the local Provincial Scientific Societies there would be some amongst their members who would be willing to supply the deficiency.

Mr. E. MAWLEY, in reply, said that it had not occurred to him to institute a comparison between the progress of vegetation in the two Jubilee years; and stated that it was not until 1889 that he had taken over the phenological work of the Society. He had not exhibited a diagram to illustrate the appearance of any of the insects, as he thought a diagram representing the arrival of some of the birds would be of more general interest. With regard to the extraordinary appearance of caterpillars mentioned by Mr. Smyth, he was inclined to think that this must have been a purely local infestation, as during the past year most insect pests appeared to have been much less numerous than usual. The blackberry blossom sent by Mr. Chandler from Torquay was a striking instance of the mildness of the present winter, and showed that the shoot bearing it must have become ripened during the autumn and started again into growth owing to the warmth of January. In respect to Mr. Hopkinson's statement as to the scanty crop of strawberries at St. Albans, he wished to state that he did not draw his conclusions from the fruit crops in his own garden, but from an analysis of hundreds of returns sent in each year by gardeners from all parts of the British Isles to the *Gardeners' Chronicle*. In looking through these returns, surprising differences in yield were often to be met with between places only a few miles apart—differences, no doubt, in most cases due to soil and situation.

MONTHLY AND ANNUAL RAINFALL IN THE BRITISH EMPIRE, 1877–96.

By JOHN HOPKINSON, F.L.S., F.G.S., F.R.Met.Soc., Assoc.Inst.C.E.

[Read February 16, 1898.]

NEARLY twenty-five years ago there appeared in the columns of *The Colonies* a letter from Mr. William Sowerby, suggesting that residents in the British Colonies should be invited to contribute to its pages, notes and queries on natural objects. This was followed by a letter from Mr. G. J. Symons, F.R.S., dated November 20, 1873, adding a similar plea on behalf of Meteorology. These suggestions met with the full approval of the Editor of *The Colonies*, who at once took steps to obtain monthly reports of meteorological observations and to have them competently examined, inviting the Directors of the principal Colonial Observatories

to supply such reports, and arranging with Mr. Symons to supervise them.

The British Empire is practically coextensive with the world, and to organise a scheme for obtaining reports on a uniform plan of meteorological observations taken in all parts of the world, from Canada to New Zealand, and from South Africa to the West Indies, was necessarily a work of time. The interval between the conception of the scheme and the appearance of the first monthly table was utilised by the publication of a series of fifteen papers contributed by Mr. Symons on "The Climatology of the British Empire."

The first monthly table published was for January 1874, and contained reports of meteorological observations taken at 16 stations in the British Empire. The tables were continued uninterruptedly to June 1881, after which date, owing to changes which took place in *The Colonies and India*, as the paper was then called, they had to be discontinued in that journal, and have appeared in *Symons' Monthly Meteorological Magazine*. In the table for December 1896 there are records from 18 stations, but only 7 of these are survivals from those in the first table, that for January 1874.

An analysis of the whole of the information contained in these 276 monthly tables would be very useful, but the compilation would be an arduous one, which could only be undertaken by some one with more leisure than the present writer. More than 50,000 values would have to be abstracted and analysed. Moreover, many stations appear in the tables for a few years only, and although some appear for a long series of years, there are many omissions, few records, if any, except that for Camden Square, London, being absolutely continuous. A summary and analysis of one element of climate only, may, however, be of some interest. Temperature, humidity, rainfall, and cloud are the elements of which particulars are given, and of these, rainfall has been selected for treatment in this communication.

The rainfall record of 10 of the 18 existing stations can be carried back for twenty years, and that of 2 for at least ten years. The 10 stations with a twenty years' record are London, England (Camden Square); Pamplemousses, Mauritius; Calcutta and Bombay, India; Colombo, Ceylon; Adelaide and Melbourne, Australia; Wellington, New Zealand; and Toronto and Winnipeg, Canada. The 2 with a ten years' record are Malta and Kingston, Jamaica. At 3 other stations the record can be carried back for five years, but this is considered to be too short a period for the present investigation.

In Tables I.–XII. are given the mean monthly and annual rainfall, and the number of days on which at least 0·01 in. of rain fell at these 12 stations, and also the maximum and minimum monthly and annual rainfall, and the number of days of rain. In the 240 monthly tables from which these have been compiled there are many omissions and a few mistakes. The whole of the omissions have been kindly supplied by Mr. Symons, and the few errors detected in the course of the investigation have been rectified by him. The sums of the monthly values have all been checked against the yearly values given in 19 published annual tables, there being no annual table for the year 1881, in which the change was made in the organ of publication. All the records are complete, except that

for Jamaica the number of days of rain has been given only for the la five years, and therefore the mean number is that for five years instea of ten, and the extremes are only for this period.

A summary of these 12 tables is given in Table XIII. The mea in this table are necessarily those of the 10 stations for which we ha records for twenty years, but the extremes are those for the whole of t 12 stations. If Malta and Jamaica had not been taken into accou there would have been a difference in the last two columns only. T minimum in June would have appeared as 0·30 in. on 4 days, in Jul 0·51 in. on 5 days, in August 0·34 in. on 2 days, in September 0·42 in. c 2 days, and in the year 14·01 ins. on 74 days.

A summary of the yearly rainfall at the whole of the 12 statio is given in Table XIV., and the mean rainfall at the 10 stations for ea of the twenty years in Table XV.

It must not be inferred that the rainfall at the places selected r presents the mean rainfall of the countries in which they are situate These places are in most cases the principal towns in those countri and it is of more general interest to know what is the climate of Lond (for instance) than what is that of any other place in Great Britai Nor are the extremes of the rainfall in the British Empire represente Colombo, Ceylon, with a mean annual rainfall of about 92 ins., and maximum of 140 ins., is altogether outdone by Rangoon, Burm where the mean annual rainfall considerably exceeds the maximum Colombo; and even in England we have a much wetter spot than Colomb The rainfall at the Stye, in Cumberland, is seldom less than 150 in per annum, and so recently as 1890 it exceeded 200 ins. Even thes quantities are very greatly exceeded at many other places in the Britis dominions. On the Khasia Hills in India the annual rainfall has bee stated to be about 500 ins. This is believed to be the wettest distri on the globe. On the other hand, there is much less rainfall in man places than there is in Malta. On the Sahara in Africa, and on the dese of Gobi in Asia, for instance, there is none at all. However, it is believe that no previous attempt has been made to ascertain the mean rainfall nearly so many as 10 widely-distributed places in the British Empire f nearly so long a period as twenty consecutive and concurrent year The observations, moreover, have been taken in an entirely unifor manner at all the stations, and are believed to be thoroughly trustworth The results are therefore strictly comparable one with another.

A few observations will now be made on the rainfall at the vario places, taking them in the order of the tables, and then a gener summary of the principal results will be given.

The results for the first 10 stations are from observations extendir over the twenty years, 1877-96.

In London, England, the rainfall is least in March and greatest October. It increases from March to July, decreases slightly in Augu and considerably in September, increases considerably in October, a decreases every month from October to March. The smallest rainfa in any month was 0·01 in. in February 1891; the largest was 6·7 ins. in August 1878. The number of days of rain per month was small as 1 in February 1891, and as great as 26 in July 1888. T driest period of a few months was from March to June 1893, wh

2·08 ins. fell, being about 0·5 in. per month for four months; the wettest period was from April to August 1878, when 22·93 ins. fell, being more than 4·5 ins. per month for five months. In the driest year (1887) the fall was 22 per cent below the mean; in the wettest (1878) it was 32 per cent above the mean.

TABLE I.—London, England. Latitude, 51° 32½′ N.; Longitude, 0° 7½′ W.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	1·85	15	4·74	25	·31	5
February . .	1·68	13	3·77	24	·01	1
March . . .	1·57	12	3·34	25	·32	5
April . . .	1·78	13	4·97	20	·24	3
May . . .	1·84	13	4·79	21	·14	3
June . . .	2·16	12	6·71	22	·30	4
July . . .	2·77	14	5·10	26	·52	6
August . .	2·58	14	6·72	22	·45	4
September . .	2·16	12	5·51	19	·64	2
October . .	2·88	16	5·78	23	·80	7
November . .	2·48	15	4·38	22	·73	8
December . .	2·01	15	4·34	21	·68	9
Year . .	25·76	164	34·09	195	19·21	137

At Pamplemousses, in Mauritius, the rainfall is least in September and greatest in March. June to November are much the driest months; January to March are much the wettest; April, May, and December are months of about average rainfall. The smallest rainfall in any month was 0·34 in. in August 1884; the largest was 30·06 ins. in February 1896.

TABLE II.—Pamplemousses, Mauritius. Latitude, 20° 20′ S.; Longitude, 57° 40′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	7·37	19	14·58	25	2·13	13
February . .	7·33	19	30·06	27	2·16	14
March . . .	8·99	21	24·11	26	2·18	15
April . . .	5·72	17	12·48	23	1·41	12
May . . .	4·07	16	13·55	23	·49	6
June . . .	2·06	16	4·36	24	·65	10
July . . .	2·40	18	5·71	24	·72	9
August . .	2·28	19	4·66	26	·34	2
September . .	1·42	15	3·59	21	·45	8
October . .	1·96	14	9·54	23	·46	3
November . .	1·90	12	9·22	18	·45	6
December . .	4·91	17	12·64	24	1·15	7
Year . .	50·38	203	71·36	241	29·74	174

The number of days of rain per month was as small as 2 in August 1886, and as great as 27 in February 1890. The driest period of a few months was from June to September 1884, when 4·14 ins. fell, being about 1 in. per month for four months; the wettest period was from

December 1895 to March 1896, when 45·53 ins. fell, being over [redacted] ins. per month for three months. In the driest year (1886) t[redacted] fall was 41 per cent below the mean; in the wettest (1877) it was [redacted] per cent above the mean.

In India, at Calcutta the rainfall is least in December and greate[redacted] in August, increasing every month from December to August, a[redacted] decreasing every month from August to December, but in a ve[redacted] irregular manner. The largest fall was 26·50 ins. in August 188[redacted] Each month from October to April has been occasionally rainless. Wh[redacted] seven months in the year have been without a day of rain, there we[redacted] 29 wet days in July 1886. The driest period of a few months w[redacted] from December 1891 to March 1892, when only 0·04 in. fell, bei[redacted] 0·01 in. per month for four months; the wettest period was from M[redacted] to July 1893, when 53·74 ins. fell, being nearly 18 ins. per mon[redacted] for three months. (From May to October in this year 78·18 ins. fe[redacted] being 13 ins. per month for six months.) In the driest year (189[redacted] the fall was 33 per cent below the mean; in the wettest (1893) it w[redacted] 44 per cent above the mean.

TABLE III.—Calcutta, India. Latitude, 22° 41′ N.; Longitude, 88° 27′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	·45	2	2·90	5	...	0
February . .	1·17	3	4·30	8	...	0
March . . .	1·28	4	3·94	9	...	0
April . . .	1·48	4	3·91	8	...	0
May . . .	5·63	10	17·11	20	1·18	4
June . . .	10·88	16	25·65	24	3·26	7
July . . .	11·95	23	18·19	29	4·53	12
August . .	12·48	23	26·50	28	4·82	15
September . .	9·06	17	16·63	21	4·03	10
October . .	3·71	7	11·08	14	...	0
November . .	·74	2	3·17	13	...	0
December . .	·37	1	2·54	4	...	0
Year . .	59·20	112	85·23	143	39·38	74

At Bombay the rainfall is least in April and greatest in July, but there is practically none in February, March, and April, and scarcely any in December and January, in most years these five months being rainless. The very wet months are June to September, but June and July have nearly twice as much rain as August and September. Each month from November to May has been occasionally without rain; the largest fall was 47·64 ins. in July 1878. While seven months in the year have been without a day of rain, rain fell every day in July in six years out of the twenty, and every day in August in three years. The driest period of several months in succession was from November 1891 to April 1892, when no rain fell, being six months without any; the wettest period was from June to September 1878, when 105·05 ins. fell, being more than 26 ins. per month for four months. In the driest year (1888) the fall was 25 per cent below the mean; in the wettest (1878) it was 46 per cent above the mean.

TABLE IV.—Bombay, India. Latitude, 18° 55′ N.; Longitude, 72° 52′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	·12	1	1·85	4	...	0
February . .	·04	0	·51	3	...	0
March . . .	·03	1	·21	3	...	0
April . . .	·01	0	·08	2	...	0
May . . .	·73	2	6·30	9	...	0
June . . .	20·36	22	43·45	28	5·11	14
July . . .	26·31	29	47·64	31	10·75	25
August . .	14·79	28	36·56	31	4·08	19
September . .	11·06	20	22·80	26	1·62	9
October . .	2·63	6	10·40	13	·01	1
November . .	·56	2	2·63	7	...	0
December . .	·07	0	1·14	3	...	0
Year . .	76·71	111	111·93	124	57·82	99

At Colombo, Ceylon, the rainfall is least in February and greatest October. It increases from February to May, decreases to August, reases again to October, and decreases to February. The smallest nfall in any month was 0·02 in. in January 1888; the largest was ·28 ins. in October 1891. The number of days of rain per month s as small as 1 in January 1888, February 1878, and February 1881, l as great as 30 in October 1885 and October 1895. The driest riod of a few months was from June to September 1880, when 5·65 . fell, being nearly 1·5 in. per month for four months; the wettest riod was from May to August 1878, when 89·63 ins. fell, being arly 22·5 ins. per month for four months. In the driest year (1892) s fall was 34 per cent below the mean; in the wettest (1878) it was per cent above the mean.

TABLE V.—Colombo, Ceylon. Latitude, 6° 58′ N.; Longitude, 79° 54′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	3·35	8	12·57	19	·02	1
February . .	2·13	6	5·32	12	·14	1
March . .	4·46	11	9·43	22	·84	5
April . . .	11·28	17	28·78	27	2·62	9
May . . .	11·76	21	22·28	28	3·00	13
June . . .	8·82	19	19·96	26	·63	9
July . . .	4·99	12	28·04	24	·52	5
August . .	4·14	14	19·54	27	·67	5
September . .	5·72	15	25·08	23	·48	7
October . .	14·97	23	35·28	30	3·45	15
November . .	13·07	19	28·78	27	4·37	10
December . .	7·13	14	17·72	22	·86	8
Year . .	91·82	179	139·70	215	60·55	128

In Australia, at Adelaide the rainfall is least in February and eatest in June, increasing each month from February to June, and

decreasing from June to February, except that October is slightly wetter than September, and January is very slightly wetter than December. In January 1878, February 1882, and February 1893, there was no rain; the largest fall in any month was 6·46 ins. in May 1883. While two months in the year have been without a day of rain, in July 1887 and July 1888 there were 26 wet days. The driest period of a few months was from December 1881 to March 1882, when 4·04 ins. fell, being about 1 in. per month for four months; the wettest period was from April to August 1883, when 18·01 ins. fell, being nearly 4 ins. per month for five months. In the driest year (1891) the fall was 32 per cent below the mean; in the wettest (1889) it was 50 per cent above the mean.

TABLE VI.—ADELAIDE, AUSTRALIA. LATITUDE, 34° 54′ S.; LONGITUDE, 138° 38′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	·86	5	2·98	12	...	0
February . .	·46	4	2·38	7	...	0
March . . .	1·23	6	4·60	10	·01	1
April . . .	2·08	10	5·65	16	·09	5
May . . .	2·49	15	6·46	22	·20	5
June . . .	3·04	18	6·02	25	·42	14
July . . .	2·64	17	5·36	26	·51	6
August . .	2·35	17	3·73	24	1·06	10
September . .	1·77	15	3·67	21	·45	11
October . .	1·81	13	3·61	19	·31	5
November . .	1·00	8	2·20	15	·04	3
December . .	·83	7	2·08	10	·18	3
Year . .	20·56	135	30·87	164	14·01	113

At Melbourne the rainfall is least in February and greatest in April and November. It increases from February to April, decreases to August, increases again to November, and decreases to February. The smallest rainfall in any month was 0·04 in. in January 1878; the largest was 7·02 ins. in July 1891. The number of days of rain per month was as small as 1 in January 1878, and as great as 20 in May 1880. The driest period of several months was from November 1878 to March 1879, when 3·74 ins. fell, being 0·75 in. per month for five months; the wettest periods were from February to May 1877, when 14·24 ins. fell, and from April to July 1891, when 14·22 ins. fell, being in each case about 3·5 ins. per month for four months. In the driest year (1895) the fall was 30 per cent below the mean; in the wettest (1887) it was 32 per cent above the mean.

At Wellington, New Zealand, the rainfall is least in February and greatest in July; October to March are the driest months, April to September the wettest. The smallest rainfall in any month was 0·13 in. in February 1880; the largest was 12·46 ins. in December 1884. The number of days of rain per month was as small as 2 in February 1880, and as great as 27 in August 1886. The driest period of a few months was from December 1886 to April 1887, when 6·98 ins. fell, being less than 1·5 in. per month for five months; the wettest period

as from May to August 1887, when 31·24 ins. fell, being nearly 8 s. per month for four months. In the driest year (1889) the fall was 3 per cent below the mean; in the wettest (1892) it was 52 per cent ove the mean.

ABLE VII.—Melbourne, Australia. Latitude, 37° 48′ S.; Longitude, 144° 59′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	1·53	7	4·75	12	·04	1
February . .	1·46	7	4·34	15	·25	2
March . . .	2·09	9	5·85	12	·24	4
April . . .	2·46	10	5·63	14	·76	6
May . . .	2·08	13	4·00	20	·76	6
June . . .	2·03	13	3·63	19	·73	9
July . . .	1·90	13	7·02	17	·65	7
August . .	1·80	14	2·97	17	·87	8
September . .	2·13	13	5·50	19	·61	8
October . .	2·40	13	3·84	19	·57	7
November . .	2·46	10	5·05	15	·25	5
December . .	2·18	9	5·13	15	·24	4
Year . .	24·52	131	32·39	153	17·06	116

In Canada, at Toronto the rainfall is least in April and greatest in ovember. The mean monthly fall is remarkably equable, the wettest onth having only about 50 per cent more rain than the driest, and ery month but April being within half an inch of the average per onth (2·62 ins.). The smallest fall in any month was 0·29 in. in

TABLE VIII.—Wellington, New Zealand. Latitude, 41° 17′ S.; Longitude, 174° 47′ E.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	3·70	11	9·58	18	0·18	3
February . .	3·02	9	7·40	13	0·13	2
March . . .	3·49	12	8·29	19	0·80	7
April . . .	4·33	13	12·15	24	1·25	6
May . . .	5·17	17	10·83	24	0·92	13
June . . .	4·88	18	9·53	24	1·60	8
July . . .	6·27	19	12·17	25	2·92	12
August . .	5·06	17	9·27	27	1·74	13
September . .	4·07	15	6·89	21	1·28	10
October . .	3·93	13	7·33	21	0·42	7
November . .	3·71	14	7·30	20	0·95	8
December . .	3·55	12	12·46	23	0·82	5
Year . .	51·22	170	67·68	191	31·37	137

ebruary 1877; the greatest was 9·37 ins. in May 1894, being an ceptionally heavy fall for the month. The number of days of rain er month has been as small as 5 in August 1894, and as great as 27 November 1892. The driest period of a few months was from ebruary to April 1895, when 2·85 ins. fell, being less than 1 in. per

month for three months (to June 6·01 ins. fell, being nearly 1·25 in. per month for five months); the wettest period was from July to September 1878, when 20·41 ins. fell, being nearly 7 ins. per month for three months (to December 31·72 ins. fell, being nearly 5·50 ins. per month for six months). In the driest year (1882) the fall was 21 per cent below the mean; in the wettest (1878) it was 54 per cent above the mean.

TABLE IX.—Toronto, Canada. Latitude, 43° 4′ N.; Longitude, 79° 25′ W.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	2·78	18	5·52	24	1·20	13
February . .	2·45	17	4·28	23	·29	6
March . . .	2·21	17	4·44	23	·77	9
April . . .	1·95	12	4·27	18	·76	6
May . . .	2·78	14	9·37	23	·53	8
June . . .	2·90	13	5·81	18	·75	6
July . . .	2·59	12	5·63	16	·66	9
August . .	2·94	11	7·09	16	·38	5
September . .	2·88	12	7·69	18	·42	6
October . .	2·39	14	4·94	20	·96	8
November . .	3·06	19	5·61	27	·61	12
December . .	2·56	18	4·90	24	·53	9
Year . .	31·49	177	48·51	206	24·83	143

At Winnipeg the rainfall is least in January and greatest in Jun[illegible] increasing each month from January to June, except that February [illegible] slightly wetter than March; and decreasing each month from June [illegible] January, except that December is very slightly wetter than Novembe[illegible]

TABLE X.—Winnipeg, Canada. Latitude, 52° 0′ N.; Longitude, 98° 0′ W.

1877-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	·83	9	1·88	16	·12	1
February . .	1·08	8	3·74	12	·10	4
March . .	1·02	8	2·48	15	·15	3
April . . .	1·81	10	5·64	14	·62	4
May . . .	2·31	11	5·85	17	·17	4
June . . .	3·34	12	7·12	18	·45	6
July . . .	3·00	13	6·61	18	·61	8
August . .	2·18	13	6·90	18	·77	7
September . .	2·02	12	4·73	18	·66	5
October . .	1·67	11	4·10	15	·33	7
November . .	·97	10	2·61	19	...	0
December . .	·99	10	2·29	15	...	0
Year . .	21·22	127	29·33	159	14·64	88

There was no rain in November and December 1883; the largest fall in any month was 7·12 ins. in June 1877. Two months in the year have thus been without a day of rain, and there were 19 wet days in November 1881 and November 1896. The driest periods of a few months were

from November 1883 to January 1884, when 0·64 in. fell, being less than 0·25 in. per month for three months, and from November 1890 to March 1891, when 2·7 ins. fell, being a little more than 0·5 in. per month for five months; the wettest periods were from May to July 1877, when 15·48 ins. fell, being 5 ins. per month for three months, and from April to July 1878, when 17·16 ins. fell, being 4·25 ins. per month for four months. In the driest year (1886) the fall was 31 per cent below the mean; in the wettest (1878) it was 38 per cent above the mean.

The results for the two following stations are from observations extending only over the ten years 1887-96.

In the island of Malta the rainfall is least in June and July, and greatest in December. June, July, and August are very dry months, and October to February are much the wettest. Each of the months from June to September has been occasionally without rain, and the heaviest fall in any month was 8·95 ins. in December 1889. Thus four months in the year have been without a day of rain, and there were 24

TABLE XI.—Island of Malta. Latitude, 35° 50′ N.; Longitude, 14° 30′ E.

1887-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January . .	3·72	15	7·82	24	1·32	8
February . .	2·39	10	5·14	12	1·08	7
March . .	1·44	7	2·71	11	·17	4
April . . .	1·10	6	3·34	11	·09	2
May . . .	·81	4	3·23	7	·02	1
June . . .	·04	1	·15	2	...	0
July . . .	·04	0	·41	1	...	0
August . .	·11	1	·56	2	...	0
September . .	·87	3	3·28	7	...	0
October . .	3·09	7	8·80	12	·65	3
November . .	2·85	10	7·33	16	·74	7
December . .	4·34	15	8·95	22	1·04	7
Year . .	20·50	79	26·04	90	11·38	59

wet days in January 1889. The driest period of a few months was from June to September 1896, when no rain fell, being four months without any; the wettest period was from December 1893 to February 1894, when 15·77 ins. fell, being about 5·25 ins. per month for three months. In the driest year (1895) the fall was 44 per cent less than the mean; in the wettest (1889) it was 22 per cent more than the mean.

At Kingston, Jamaica, the rainfall is least in January and greatest in October. It is very irregular, but December to April are the driest months, May and October are the wettest, and June and September follow. No rain fell in March 1893, and 22·13 ins. fell in May 1888. (In June 1886, 32·07 ins. fell.) Thus one month has had no day of rain, and there were 22 wet days in October 1892. The driest periods of a few months were from November 1889 to February 1890, and from December 1891 to March 1892, in each of which periods 0·91 in. fell, being less than 0·25 in. per month in each case; the wettest period was from May to October 1887, when 34·79 ins. fell, being nearly 6 ins.

per month for six months. In the driest year (1896) the fall was 30 per cent below the mean; in the wettest (1888) it was 40 per cent above the mean.

TABLE XII.—KINGSTON, JAMAICA. LATITUDE, 18° 12′ N.; LONGITUDE, 77° 30′ W.

1887-96.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January	·53	4	1·70	7	·05	1
February	·84	5	2·40	8	·11	3
March	1·10	3	5·43	6	...	0
April	·97	6	1·84	8	·26	5
May	5·19	9	22·13	12	1·07	6
June	3·36	7	12·18	10	·32	3
July	1·95	7	7·10	14	·20	3
August	2·38	7	5·23	9	·40	5
September	3·12	8	6·67	12	1·54	6
October	6·50	14	12·78	22	·97	5
November	2·00	9	3·95	12	·07	3
December	1·22	6	3·29	9	·01	1
Year	29·16	85	40·81	97	19·01	78

Throughout the British Empire, so far as appears from the results of observations at the 10 stations for which we have returns for the last twenty years, the rainfall is least in February and greatest in July, increasing every month from February to July, and decreasing every

TABLE XIII.—MEAN RAINFALL, AND NUMBER OF DAYS ON WHICH AT LEAST 0·01 IN. FELL AT 10 STATIONS IN THE BRITISH EMPIRE, AND EXTREMES AT 12 STATIONS.

Months.	Mean.		Maximum.		Minimum.	
	Ins.	Days.	Ins.	Days.	Ins.	Days.
January	2·28	9	14·58	25	...	0
February	2·08	9	30·06	27	...	0
March	2·64	10	24·11	26	...	0
April	3·29	11	27·78	27	...	0
May	3·89	13	22·28	28	...	0
June	6·04	16	43·45	28	...	0
July	6·48	17	47·64	31	...	0
August	5·06	17	36·56	31	...	0
September	4·23	15	25·08	26	...	0
October	3·84	13	35·28	30	...	0
November	3·00	11	28·78	27	...	0
December	2·46	10	17·72	24	...	0
Year	45·29	151	139·70	241	11·38	59

month from July to February. The fall in July is more than three times as much as the fall in February. The increase is greatest from May to June, being over 2 ins.; the decrease is greatest from July to August, being nearly 1·5 in. The number of days of rain varies in a similar manner, being least in January and February, and greatest in July and August.

Taking now into consideration also the two stations with records for

least the last ten years, it will be seen that there may be no rain at ne one or more of these 12 rainfall stations in the British Empire in y month in the year up to six months in succession. This has only urred at Bombay, and but once in the twenty years. The heaviest

BLE XIV.—Mean and Extreme Yearly Rainfall, and Number of Days of Rain at 10 Stations in the British Empire for Twenty Years, and at 2 for Ten Years.

Months.	Mean.		Maximum.		Minimum.	
1877-96.	Ins.	Days.	Ins.	Days.	Ins.	Days.
London	25·76	164	34·09	195	19·21	137
Mauritius	50·38	203	68·17	241	29·74	174
Calcutta	59·20	116	85·23	143	39·38	74
Bombay	76·71	111	111·93	124	57·82	102
Colombo	91·82	179	139·70	215	60·55	128
Adelaide	20·56	135	30·87	164	14·01	113
Melbourne	24·52	132	32·39	153	17·06	116
Wellington	51·22	170	67·68	191	31·37	137
Toronto	31·49	177	48·51	206	24·83	143
Winnipeg	21·22	127	29·33	159	14·64	88
1887-96.						
Malta	20·50	79	26·04	90	11·38	59
Jamaica	29·16	85	40·81	97	19·01	78

nfall in any month was 47·64 ins. at Bombay in July 1878; here, l here only, has there been rain on every day in any month, and t has occurred several times in both July and August. In Malta, in year 1895, the rainfall was only 11·38 ins.; in Ceylon, in the year 78, it was as much as 139·70 ins. Thus there has been more rain month in one year in Ceylon than there has been in a whole year Malta. In Malta, in the year 1888, there were only 59 days of rain; Mauritius, in the year 1893, there were 241 wet days.

TABLE XV.—Mean Rainfall at 10 Stations for each of the Twenty Years, 1877-96.

Year.	Amount.	Ratio.	Days.	Year.	Amount.	Ratio.	Days.
	Ins.				Ins.		
1877	48·98	108	150	1887	46·08	102	155
1878	56·74	125	147	1888	42·73	94	154
1879	42·43	94	148	1889	44·96	99	153
1880	43·14	95	155	1890	43·00	95	161
1881	44·48	98	148	1891	44·29	98	154
1882	44·13	97	146	1892	45·08	100	152
1883	47·19	104	148	1893	48·31	107	159
1884	44·87	99	144	1894	41·19	91	154
1885	42·05	93	150	1895	42·11	93	146
1886	45·13	100	150	1896	48·97	108	143

If the twenty years be divided into four periods of five years each vill be found that the mean annual rainfall at the 10 stations has n as follows: in the first period 47·15 ins. on 150 days; in the

second period 44·67 ins. on 148 days; in the third period 44·21 ins. on 155 days; and in the fourth period 45·13 ins. on 151 days. This does not show any very great variation except in the first period (1877-81). This was an exceptionally wet period in England, owing to the very wet year 1878, which from this investigation appears to have been generally wet over the globe. Probably the divergence between the different periods would be less if more places were represented. Even by including Malta and Jamaica the divergence between the last two periods is reduced from nearly an inch to rather less than half an inch.

The mean annual rainfall at the 10 stations for the first ten years was 45·91 ins. on 149 days, and for the last ten years 44·67 ins. on 153 days, a decrease of an inch and a quarter.

The mean annual rainfall for the whole period was 45·29 ins. on 151 days.

In this account of the rainfall at a few meteorological stations in the British Empire the effects of seasons have been altogether neglected. Six of the stations with records for twenty years are north of the equator, and four are south of it,—not a very great inequality, and not nearly representing the preponderance of land in the northern hemisphere over that in the southern. In England the wettest period is nearly the same as in New Zealand, but it happens to occur in the summer and autumn in England but in New Zealand in the winter and spring. And taking each table individually there seems to be very little correspondence between the rainfall and the season at each place. It does not appear to be the succession of the seasons which causes the rainfall to increase generally each month from February to July, and to decrease each month from July to February, although the very heavy rainfall at Bombay in June and July tells much in making those months appear to be so wet generally. With a larger number of stations any such disturbing influence as this would have less effect on the general result.

DISCUSSION.

The President (Mr. F. C. Bayard) said the thanks of the Society were due to Mr. Hopkinson for his interesting paper, which would no doubt give rise to a great deal of discussion, probably owing to the small number of stations included therein. Both the paper and accompanying tables were well worthy of careful consideration and study.

Mr. B. Latham said that he thought the paper reflected great credit on the author. It was very curious that, with the exception of Toronto, a large majority of the values bore out the old rule that the addition or subtraction of one-third to or from the average gave the maximum or minimum rainfall, as the case might be. He thought papers of this kind encouraged people to contribute observations. It certainly must have involved a large amount of time and labour to condense such a number of observations.

Mr. O. Chadwick said he was interested in the paper inasmuch as it touched on many parts of the world with which he had at different times been connected. In the paper, observations were given as taken at Port Louis. He was not aware of any observatory at Port Louis. The Government observatory was at Pamplemousses, some miles away, which would represent a great differ-

ence in a country like Mauritius, where the variation of rainfall was very great. So great is this, that 15 miles from Port Louis the rainfall is as much as 130 ins. per annum, while a few miles south of that town the yearly total is below 30 ins., no vegetation growing without irrigation. The total rainfall given in the paper for Malta agreed exactly with his own observations. He thought there were many more years' statistics available than those cited in the present paper. As with Mauritius the rainfall given for Kingston, Jamaica, did not in any way represent the whole country; and in the neighbourhood of the Blue Mountains it greatly exceeded this, there being great variation of rainfall in that island considering its size.

Mr. G. J. SYMONS said he had recently made a rough estimate of the number of rain gauges in use over the globe, and the conclusion he had come to was that the total did not fall short of 25,000, the analysis of whose records were far too much for any single individual. But in nearly all countries, there were organisations in existence which were engaged in the collection, tabulation, and publication of the results; so that it could be hoped in time that by a combination of the whole a good rainfall atlas might be prepared. For instance, Blanford's Rainfall Map of India, and those published for Australia, Mauritius, Jamaica, etc., would each form a valuable and interesting part. He could not speak so well for the observations carried on in the United States, as the gauges had too frequently been placed on the tops of high buildings, but good work was being done in Canada by Mr. Stupart. A good point in the paper before them was that the observations at the various places were for concurrent years. It would be interesting to see if there were any relation in the variation of rainfall with the appearance of sun-spots, and whether anything like a regular curve could be obtained even with so small a number of observations. For this purpose it was requisite to have synchronous observations over a very large area indeed.

The President (Mr. F. C. BAYARD) thought it would add to the value of the paper if the maximum and minimum years of the period discussed by the author were also given.

Mr. J. HOPKINSON, in reply, said that in compiling the paper he had no intention of giving the mean rainfall of the different countries, but simply a summary of the results of observations made at certain towns in the Empire, of which the publication was commenced in *The Colonies and India* and continued in the *Meteorological Magazine*, and he had selected for analysis those observations only which had been taken continuously for at least the ten years ending 1896, all but two affording a continuous and concurrent twenty years' record.

PROCEEDINGS AT THE MEETINGS.

January 19, 1898.

Ordinary Meeting.

EDWARD MAWLEY, F.R.H.S., President, in the Chair.

SAMUEL BARKER, F.R.A.S., 9 Hanover Terrace, Regent's Park, N.W.;
ROBERT THOMAS FORD, Sunbeam, Windermere;
LEON FRANKLIN, 19 Gower Street, W.C.;
GEORGE GÔUT, Beilby House, Cleethorpes;
TOM GEORGE LONGSTAFF, B.A., Christ Church, Oxford; and
Mrs. ENRIQUETA RYLANDS, Longford Hall, Stretford, Manchester,

were balloted for and duly elected Fellows of the Society.

January 19, 1898.

Annual General Meeting.

EDWARD MAWLEY, F.R.H.S., President, in the Chair.

Major L. FLOWER and Major H. KING were appointed Scrutineers of the Ballot for Officers and Council.

Mr. F. C. BAYARD read the Report of the Council and the Balance-Sheet for the year 1897 (p. 83).

It was proposed by the PRESIDENT, seconded by Mr. F. C. BAYARD, and resolved: "That the Report of the Council be received and adopted, and printed in the *Quarterly Journal*."

It was proposed by Dr. J. W. MOORE, seconded by Mr. W. B. HEBERDEN, and resolved: "That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Dr. H. R. MILL, seconded by Mr. F. J. BRODIE, and resolved: "That the thanks of the Society be given to the Standing Committees and to the Auditors, and that the Committees be requested to continue their duties till the next Council Meeting."

It was proposed by Dr. C. T. WILLIAMS, seconded by Mr. A. BREWIN, and resolved: "That the most cordial thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers, and also of the Royal Astronomical Society, for having granted the Society free permission to hold its meetings in the rooms of their respective Institutions."

The PRESIDENT then delivered an Address on "WEATHER INFLUENCES ON FARM AND GARDEN CROPS" (p. 57).

It was proposed by Mr. G. J. SYMONS, seconded by Mr. R. INWARDS, and resolved: "That the thanks of the Society be given to Mr. EDWARD MAWLEY for his services as President during the past year, and for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal*."

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year:—

PRESIDENT.

FRANCIS CAMPBELL BAYARD, LL.M.

VICE-PRESIDENTS.

GEORGE CHATTERTON, M.A., M.Inst.C.E.
RICHARD HENRY CURTIS.
WILLIAM HENRY DINES, B.A.
HUGH ROBERT MILL, D.Sc., F.R.S.E., F.R.G.S.

TREASURER.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

SECRETARIES.

EDWARD MAWLEY, F.R.H.S.
GEORGE JAMES SYMONS, F.R.S.

FOREIGN SECRETARY.

ROBERT HENRY SCOTT, M.A., F.R.S.

COUNCIL.

RICHARD BENTLEY, F.L.S., F.R.G.S.
FREDERICK JOHN BRODIE.
Capt. ALFRED CARPENTER, R.N., D.S.O., F.Z.S.
OSBERT CHADWICK, C.M.G., Assoc.M.Inst.C.E.
HENRY NEWTON DICKSON, F.R.S.E., F.R.G.S.
WILLIAM ELLIS, F.R.S., F.R.A.S.
WILLIAM BULLER HEBERDEN, C.B.
RICHARD INWARDS, F.R.A.S.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
Vice-Admiral JOHN PEARCE MACLEAR, R.N., F.R.G.S.
CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.
Capt. DAVID WILSON-BARKER, F.R.S.E., F.R.G.S.

MAWLEY having left the chair, it was taken by Mr. F. C. BAYARD, elected President, who thanked the Fellows for having elected him ice.

February 16, 1898.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

ES HENRY GATTY, M.A., LL.D., F.R.S.E., Felbridge Place, East ;
EORGE THOMAS LAYCOCK, Terwick, Petersfield ; and
ARRY WEBB, Ferlie, Cambridge Road, King's Heath, Birmingham, ted for and duly elected Fellows of the Society.

ER G. DAVIS, Director of the Oficina Meteorológica Argentina, Cor-l

P. VAN DER STOK, Director of the Magnetical and Meteorological ry, Batavia,
ted for and duly elected Honorary Members of the Society.

llowing communications were read :—

ORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1897." By EDWARD F.R.Met.Soc., F.R.H.S. (p. 123).

THLY AND ANNUAL RAINFALL IN THE BRITISH EMPIRE, 1877 TO 1896." HOPKINSON, F.R.Met.Soc., Assoc.Inst.C.E. (p. 148).

CORRESPONDENCE AND NOTES.

ıtation of the Albert Medal to Mr. G. J. Symons, F.R.S.—The f the Society of Arts attended at Marlborough House on Saturday, 26, 1898, when His Royal Highness the Prince of Wales, K.G., of the Society, presented the Albert Medal to Mr. George James '.R.S., "for the services he has rendered to the United Kingdom by o engineers engaged in the water-supply and the sewage of towns a y basis for their work, by establishing and carrying on during nearly ı systematic observations (now at over 3000 stations) of the rainfall ish Isles, and by recording, tabulating, and graphically indicating the these observations in the annual volumes published by himself."

Study of Special Cloud Forms.—Mr. A. E. Sweetland has for some time past been making observations of clouds at Winthorpe, Mass., on the same lines as those employed at the Blue Hill Observatory. He has also used the detailed nomenclature devised by Mr. H. H. Clayton, which is much more extensive than the International system. He has combined his observations with those made at the Blue Hill Observatory, and from this discussion has obtained the following conclusions:—

1. *Cirrus plumes* precede fair weather.

2. *Grano cirro-cumulus* is a rainy weather cloud, and was in every case found in the south or south-west quadrant of the cyclone.

3. *Mammillated* clouds in the three upper levels precede fair weather, in the two lower levels rain.

4. *Stratus nimbiformis* and *lenticular* clouds are the forms most frequently followed by rain.

5. *Flocculent cirrus*, *lenticular* clouds, and *alto-cumulus squamosus* precede great falls in temperature. These clouds are similar in showing fleecy or flocculent forms when near the zenith, but they float at different levels.

6. *Undulatory* clouds at all levels precede warmer weather and rain.

7. *Cumulus castellatus* is connected with thunderstorms, and precedes the greatest fall in temperature of any of the cloud forms examined.

8. Flat and flaky clouds, as *alto-cumulus squamosus*, clouds forming and disappearing, and clouds changing to forms of a higher average level, occur in the rear of cyclones and in the front of anticyclones, and hence precede dry and cooler weather.

River Bars and Ocean Currents.—In connection with the Buffalo River, South Africa, Capt. A. E. Pakeman supplements his former communication on this subject (*Quarterly Journal*, vol. xxii. p. 230) by a further account of the scouring influence of the colder and denser Polar current, moving parallel to, but in opposite direction to, the warm Equatorial current. He shows that from its greater density the Polar current has a greater disturbing influence on the belt of sand along the shore, and moves it outside the surf line and beyond the sphere of ordinary wave action.

This influence varies according to the velocity of the current, being increased during the summer by gales. In the summer, especially after South-east gales, the condition of the bar is improved; whilst in winter the shoaling is gradually increased. In fine weather, when there is no evidence of a Polar current, as before an Easterly wind, the water is clear, and there is no scouring. Capt. Pakeman has for some years taken observations of the temperature and the specific gravity of the water, from which he draws these conclusions, and he proposes a plan of utilising this scouring current to keep the river-mouth clear.

The Hydrography of the United States.—At the meeting of the British Association held last year at Toronto, Mr. F. H. Newell, Chief Hydrographer U.S. Geological Survey, read a paper on this subject, in which he said that the results of the various branches of hydrographic investigation, when rounded out, give a complete history of the progress of the cycle of existence of water from the time it reaches the earth as rain until it is again returned to the air by evaporation, or fixed more or less permanently in the tissues of plants or the rocky crust of the earth. This life-history embraces not only the progress of the water from point to point, but also its quantity, distribution, extent, and depth in the rivers and lakes and on navigable coasts. The progress of events in such a history can be discussed under several heads, the principal of which are the quantity and distribution of rainfall, the amount of water which runs off the surface of the ground to form streams, commonly known as the "run-off";

next, the portion which is early evaporated from the soil, or from plants growing in it, is considered ; and, lastly, that which sinks under ground, percolating for considerable distances to form relatively permanent ground waters, or to reappear, in part at least, in springs and ordinary or artesian wells.

The great body of facts thus far acquired consist of measurements of rainfall made by the Weather Bureau, of records of river height kept by this organisation and by various officers, of the army, together with occasional discharge measurements made at irregular intervals. To these must be added the measurements and computations of daily and monthly discharge of various streams resulting from the field work of the Geological Survey, and a considerable body of facts relating to the occurrence and movement of water under ground, resulting from the studies of various geologists. This somewhat heterogeneous mass of material is being digested as rapidly as possible by the Division of Hydrography of the Geological Survey, with the intention of preparing a systematic description of the hydrography of the United States.

One of the first results to be attained, but one for which many more facts are needed, is the relation existing between rainfall and run-off under various conditions of topography and culture. Tentative conclusions have been drawn and expressed in the form of simple diagrams. If all the rain that fell upon the surface flowed off in the streams as from a roof, then with, say, 40 inches of annual rainfall there would be an equivalent depth of 40 inches of annual run-off ; but, as a matter of fact, from the ordinary mountainous country only about 30 inches in depth of run-off may be expected, and from surfaces of less relief, as the rolling prairies and foothills, about 15 inches in depth of run-off per year. On the other hand, with 20 inches of rainfall, the amount running off from the mountainous country is approximately 7 inches, and from the prairies 2 inches. With half as much rainfall, or 10 inches in depth, only about 2 inches per year can be expected from the mountains, and practically nothing from the plains. In other words, with a mean annual rainfall of less than 10 inches, or from 10 to 15 inches, no living streams can be expected outside of the mountains ; and, as shown by the map of the United States, rivers rising in regions of such aridity disappear upon reaching the lowlands, so that the great arid region of the west is characterised by its lost streams.

Another set of results that are being obtained regards the average discharge of the rivers of the country. It is recognised that, with the great seasonal and climatic oscillations that take place, the streams have great range, and may never flow for any considerable length of time at their average rate ; but, nevertheless, even with these wide and irregular variations, it is a matter of considerable moment to know what has been for a period of ten years or more the average discharge of the streams at certain points. This average discharge, when represented diagrammatically on a map, enables the student to see at a glance the relative importance of various rivers, as well as their length and position.

The average quantity of water carried by rivers at various portions of their course being ascertained approximately, it becomes practicable, upon this basis, to study the variations from the mean, and to fix a standard by which to express the relative excess of floods or the relative deficiency of droughts. The intensity and duration of these are matters of great importance, both in their practical and scientific application, and can only be satisfactorily discussed when results have been obtained covering a considerable range of time. When such data have been assembled and arranged for convenience of reference, it will be possible for individuals—officials, engineers, or promoters—to discuss the practicability of enterprises designed to promote the health, comfort, or wealth of the people.

Unusual Darkness.—Miss E. Brown, F.R. Met.Soc., of Further Barton, Cirencester, writes :—

"On March 3, 1898, at 4.45 p.m., after a slight shower of snow earlier in the afternoon, a dense canopy of cloud passed over Cirencester and the neighbourhood, drifting slowly from north-east to south and causing darkness equal to that of night.

"Persons walking out of doors had a difficulty in finding their way, all dwellings had to be lighted up. Occasionally drops of "graupel" fell from this darkened sky, which assumed a very lurid tint. The sun, at the time far from the horizon (Cirencester being nearly 2° W. of Greenwich), showed through this pall of gloom of a red colour. This strange phenomenon lasted about half an hour. There was throughout a faint band of light on the horizon in the south and west. About five miles distant to the north-east at Foss Cross, on the old Roman road, a heavy shower of hail fell.

"The darkness was not observed either in Cheltenham or Bath."

A similar phenomenon at the same time was experienced for many miles to the south of London.

RECENT PUBLICATIONS.

A Légnyomás a Magyar Braodalomban, 1861-*töl* 1890-*ig*. Irta RÓNA ZSIGMOND. 1897. 8vo. 204 pp.

This is an elaborate paper on the barometric pressure of Hungary, printed in the Magyar language, with an appendix in German, which gives a summary of the contents. The paper deals with all the available stations in Hungary for the 30 years 1861-90, and the appendix gives a clear account of the methods adopted in each branch of the investigation.

Annuaire de la Société Météorologique de France. October to December 1896. 4to.

The principal articles are :—Trente années d'observations météorologiques à Cannes : by Dr. de Valcourt (26 pp.).—Note sur les pluies des 10 et 11 Juin 1896 en Normandie : by G. Guilbert (2 pp.).

Journal of Balneology and Climatology. Vol. II. Parts I. and II. January and April 1898. 8vo.

This is the Journal of the British Balneological and Climatological Society, and contains original articles, and reports of the proceedings and discussions of the Society, as well as reports and statistics from health resorts, etc. Amongst other articles are the following :—A Proposal to establish Chairs of Medical Climatology and Medical Geography in the British and Colonial Schools of Medicine : by A. Haviland.—Hygienic and Climatic Characteristics of the South-Western Promontories of Ireland : by Dr. P. Letters.—Bundoran as a Health Resort : by Dr. R. H. Creighton. Bundoran is a small town on the south shore of Donegal Bay.

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. January and February 1898. 4to.

The principal articles are :—Einige Barogramme und Thermogramme von Thal und Bergstationen : von M. Margules (16 pp.). This is a discussion of a

number of records from Richard's barograms and thermograms at some of the Austrian mountain stations in comparison with those from adjacent valley stations, especially during thunderstorms. The author shows that hardly any of the sudden jumps which we notice at our stations near the sea-level are traceable at the level of 6000 feet. Ben Nevis is hardly high enough to test this thoroughly, but it is probable that an examination of its records with those of Fort-William might present some features of interest.—Die Winterwinde des nordatlantischen Oceans und die afrikanische Antimonsune: von Dr. W. Zenker (13 pp.). The editors of the *Zeitschrift* have given a special disclaimer of their responsibility for the views of the author of this paper. The reasoning is based on the principles enunciated in the author's work "Der thermische Aufbau der Klimate," which appeared in 1895, and Dr. Zenker proceeds to calculate what he calls "Oceanities"!! He says the origin of the winter winds is to be found over the ocean, and that of the summer winds over the continent. He goes on to prove that the centres of origin of all these winds are at points very far distant from where the winds are felt. The whole paper requires to be carefully studied to follow the reasoning.—Ein Versuch, die bei Blitzschlägen erreichte maximale Stromstärke zu schätzen: von F. Pockles (6 pp.). The author makes no mention of the calculations of the potential necessary to produce a flash of lightning a mile in length which are given in the *Philosophical Transactions*, vol. clxix. The result at which Dr. Pockles arrives is that the force of the current of a lightning flash is certainly 10,000 ampères, and probably even greater than that.—Siacci's Formeln zur Darstellung der Resultate der Ballonfahrten Glaisher's: von H. Hartl (9 pp.). This is a reproduction in German of a paper in the *Atti* of the Naples Academy.

Report of the Sixty-Seventh Meeting of the British Association for the Advancement of Science held at Toronto in August 1897. 8vo. 1898. 907 pp.

Among the papers read at the Meeting of the Association were the following: Report on observations at the Ben Nevis Observatory. Report on the application of Photography to the elucidation of Meteorological phenomena. Monthly and annual rainfall in the British Empire, 1877-96: by J. Hopkinson. On the temperature of Europe: by Dr. van Rijckevorsel. On the climate of Canada: by R. F. Stupart. The great lakes as a sensitive barometer: by F. N. Denison. Slow refrigeration of the Chinese climate by Dr. J. Edkins. Progress of the exploration of the air with kites at Blue Hill Observatory, Mass., U.S.A.: by A. L. Rotch. Kites for meteorological uses: by C. F. Marvin. Report on the climate of Tropical Africa. Sea temperatures north of Spitzbergen: by B. L. Smith. The United States Daily Weather Survey: by Prof. W. L. Moore.

Results of Rain, River, and Evaporation Observations made in New South Wales during 1896. By H. C. RUSSELL, B.A., C.M.G., F.R.S., Government Astronomer. 1897. 8vo. 209 pp., with maps and diagrams.

Mr. Russell continues to extend his rainfall organisation, the number of observing stations having increased to 1463. The year 1896, like 1895, was a year of severe drought all over the colony, with the exception of two comparatively small areas. In the southern districts the drought was intense, and was productive of great loss. The average rainfall for the whole colony was 22·26 ins., which is 10 per cent more than it was in 1895, but still 12 per cent below the average.

Symons's Monthly Meteorological Magazine. January to March 1898.

The principal articles are :—Gale of November 28, 1897 (4 pp.).—Incli
Air Currents : by Major-Gen. H. Schaw (2 pp.).—Meteorological Observation
Camden Square, London, N.W. (4 pp.). In the February number Mr. Syn
commences a series of monthly articles, giving the results of his observation
Camden Square for the forty years 1858-97.—Warmth, Dryness, and
Barometer in January, 1898 (3 pp.).—West of England Snowstorm, Febr
21, 1898 (4 pp.). A foot of snow or more fell on this date in parts of Ha
shire, Dorset, Devon, and Somerset. In the neighbourhood of Milverton
Crewkerne the depth was about two feet.

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PHOTOGRAPHING METEOROLOGICAL PHENOMENA.

BY ARTHUR W. CLAYDEN, M.A., F.R.Met.Soc., Principal of the Exeter Technical and University Extension College.

A Lecture delivered before the Royal Meteorological Society, March 16, 1898.

PHOTOGRAPHY has gradually won so important a place among the means available for research in all branches of science, that when I received an invitation from the Council to deliver a Lecture upon its relations to meteorology, I had some misgiving as to whether it would be possible to do full justice to such a theme in a single Lecture. It would manifestly be impossible to give anything like a full description of what has been done, and is being done at present, in the way of photographing meteorological phenomena in all parts of the world. Even an adequate account of what has been done in our own country would take far more time than I have at my disposal to-night. Hence I propose to restrict myself to general principles, and to endeavour to illustrate those principles by reference to the special applications of meteorological photography which have come within my own personal experience.

Some idea of the importance of the camera as a meteorological instrument may easily be gained by counting how many of the papers brought before this Society are more or less dependent upon photographic methods, either for the information they contain or for the clear exposition of argument or fact.

Eight years ago, at the meeting on March 19, 1890, the late Mr. G. M. Whipple brought before the Society an account of the various recording instruments at Kew in which some form of photographic registration is adopted. This paper[1] may well be taken as a sufficient exposition of the numerous applications of the method of registration which has been more and more widely adopted since its first introduc-

[1] *Quarterly Journal*, vol. xvi. p. 141.

tion in 1838. Barometers, thermometers, magnetometers, and electrometers can now all be watched by an observer who is always there, who is always looking in the right direction, whose attention does not flag, and who cannot easily make an erroneous record, if only he is properly adjusted and properly wound up at the appointed time. Our registers of sunshine are all photographic, whether we take the Campbell-Stokes' recorder, which uses mainly rays of low refrangibility, or the modified cameras of Jordan and M'Leod.

The essential advantage of all these applications is that there is no mechanical connection between the instrument and the recording surface, that connection being made either by the movements of a pencil of rays or by the variation in the position of the edge of a shadow. These movements are frictionless, so that there is no resistance to be overcome, no lagging of the record behind the fact, no pen to be adjusted with sufficient, but not excessive, pressure, no ink to dry up or catch dust to clog the pen or smudge the record. As time goes on it seems certain that these photographic methods will more and more replace the various other devices for securing a continuous record. Indeed, were it not that such instruments are necessarily costly to construct, they ought rapidly to displace the intermittent observations with which we meteorologists who carry on our work apart from the great observatories have generally to be content.

Now although the movements of these instruments are most essentially meteorological phenomena, and although the tracing of the record is undoubtedly "photographing," I feel sure I shall be allowed to leave that part of my subject without apology.

Use of Photography for Recording Unusual Events.

As a means of recording unusual phenomena, or at least some of their results, the gelatine plate has given us an invaluable ally. Here, again, I have been anticipated. When Mr. Whipple read the paper which I have already cited, he was followed by Mr. W. Marriott with a discussion of the "Applications of Photography to Meteorological Phenomena," a paper[1] illustrative of an Exhibition organised by this Society, and open from 18th to 21st March of the same year. Several of the lantern slides I shall presently show have been copied from pictures exhibited at that time.

Now it would seem that nothing would be easier than to organise a great army of observers, each capable of taking a creditable photograph, and who would be ready to go and secure a record of anything worth noting which might occur in their immediate neighbourhood. It was with this idea in my mind that I set to work some seven years ago as Secretary of a Committee of the British Association. I had before me the example of the vast system of observers organised by Mr. Symons all over the country, and hoped that something of the sort, but of course on a very much smaller scale, could be arranged. Careful instructions were sent out, promises of assistance came from all parts of the world, and a considerable number of photographs was rapidly accumulated, which collection I hope will, before this summer is over, be safely placed in the library of this Society. Had it been desirable,

[1] *Quarterly Journal*, vol. xvi. p. 146.

there is no limit to the number of photographs of clouds, lightning, hoar-frost, snow scenes, and the like, which could have been accumulated. But this Society already possesses a fine and typical collection, and we soon felt that it was quite useless to go on accumulating duplicates. Now came the difficulty. Events occurred every now and then, such as unusual damage by lightning or by tempest, exceptionally heavy floods, altogether abnormal frost, such as the great frost of the early part of 1895. I found how wide a difference there is in getting others to act on their own initiative, and in getting them to fulfil some definite appointed task.

Most instances of damage cause inconvenience to some one or other, and the traces of destruction are often cleared away so much in a few hours that a photograph would be deprived of nearly all its interest. It is not possible for any central officer to read of the event in the newspaper and then send instructions to the photographer. Thus phenomenon after phenomenon passes unregistered. No doubt a great number of records are preserved, but only too frequently they are of little scientific value, either for want of any scale by which the dimensions of the objects shown may be estimated, or by the absence of any companion photograph of the same scene taken under normal conditions. A photographer generally takes his views with an eye to pictorial effect, and does not often care to spoil his plate by inserting anything so ungainly as a yard measure. It has been repeatedly pointed out that for many purposes any object of commonly recognisable dimensions will fully suffice, but there seem only two ways of getting records of the kind we want, and they are in the multiplication of people who are both photographers and meteorologists, or in securing a number of local meteorologists who will undertake to try and get some photographing friend of theirs to take suitable views whenever opportunities come.

Many instances have come under my notice in which pictures have been taken in such a way as to completely fail to give the record desired. It would be invidious to show examples of these, but I can show some examples of records whose value would have been greatly increased by companion pictures taken from the same point of view, and with the same apparatus, but under ordinary meteorological conditions. Two pictures of floods will illustrate this, and a fine photograph of hailstones from the Society's collection shows another convenient manner of securing a scale in that the picture is the same size as the object. I mean the picture on the lantern slide.

Another use for the camera is in the study of the minute details of short-lived phenomena. For instance, few things are more beautiful than hoar-frost, but few things are more fragile or more transient. Thus it comes about that it presents several points of interest which I do not think have yet met with a complete explanation. Here is a photograph of a piece of string thickly coated with rime. We see at once how densely clustered are the crystals about the slender threads where the string has been frayed out. This is a fact always to be observed. It is illustrated also by a photograph of a briar rose showing the crystals but thinly deposited on the main stems and shoots, but clustered in beautiful tassels on every prickle.

Again, in this photograph of a young sapling the rime is thick on one side, absent from the other. It is thick on the side which faced the drift of the frosty fog, having clearly grown outwards to meet the wind. Is this due to a difference of temperature, or to the water particles in the drifting fog having collided with the obstacle and then crystallised?

Still other illustrations of hoar-frost are afforded by the way it is deposited around the margins of leaves rather than on their surfaces, while it is evenly crusted all over such good conducting bodies as an iron railing or wire netting (Fig. 1).

FIG. 1.—Hoar-frost.

However, my time is not unlimited, so I must curtail what I have to say. The possibilities of use for the camera are innumerable, and I have said enough to indicate the lines which these may follow. There are two very important parts of our science in which it has already given us information of the highest value. These are in the study of lightning and in the observation of clouds.

Much of what I have now to say has already been placed before this Society in one form or another, but some years have elapsed since that time, and I take it the Council, in inviting me to discuss such things to-night, must have wished to have a summary of the subject put before the Fellows who have more recently joined the Society.

Photographs of Lightning.

It was, I think, in 1887 that the Society appointed a special committee called the Thunderstorm Committee. I need not now refer to the conclusions arrived at by that body. They are given in the back numbers of our *Quarterly Journal*. The great thing from our present point of view was the beginning of a collection of lightning photographs. A good deal relative to the phenomena revealed has also been discussed in the Annual Reports of the British Association from 1891 to 1897, and

as some of these conclusions have not yet been published elsewhere they may be worth repeating to-night.

Many photographs show the flashes branching in the manner familiar to us all, but it is a singular fact that when the discharge passes between the clouds and the earth these branches are always directed downwards. Among all the large number of photographs which I have seen, I have only met with one exception to this; and on investigating this with a lens to see whether anything analogous to retouching had been employed—well, I felt convinced that the photograph did not afford an exception to the rule.

Very many of these photographs show the flash as a narrow ribbon-shaped band. This was not expected, and a good deal of discussion has centred upon it. In the first place, it will be granted that the flash must have some dimensions other than length; and I may ask why should it be presumed that those dimensions are equal? Why

FIG. 2.—Lightning (Negative).

should we take it for granted that the flash has the same form as a bent wire? The apparent flattening would be easily produced by even a small difference in the transverse diameters, and my own full belief is that the majority of flashes might well be imitated by bending a wire which had been previously rolled into an elliptic section. If the phenomenon were merely an optical effect, as many experts argue, it ought to be most marked in the marginal portions of the plate, which is by no means the rule, and it should be best seen where the flash is brightest, whereas, on the contrary, it is frequently best seen in the fainter branches. The slides we project on the screen show these phenomena, the ribbon structure being specially well shown in an enlarged negative of part of a flash (Fig. 2).

Another unexpected phenomenon was the frequent reduplication of the flash. This has revealed the fact that a distinction must be drawn between a "flash" and a "discharge." The discharge may of course be limited to a single flash, but it is often composed of a volley of flashes. Dr. Hoffert's famous photograph, with which probably all meteorologists are familiar, shows the resolution of a discharge into its component flashes and into the persistent luminosity which I have suggested is the flame of burning nitrogen, while others prefer to suppose it is due to

phosphorescence of oxygen in the air. As a matter of fact, we know that the nitrogen is burnt by the flash, and that very high tension discharges will always make a flame about the nature of which there is no doubt; and it seems more reasonable, on the whole, to hold the combustion view until some definite evidence can be adduced to disprove it. Possibly both explanations are true.

Perhaps the most contentious result of lightning photography was the question of reduplication. Do the flashes in a discharge follow the same path, and are these multiple flashes all obtained by movement of the camera? Or does the path shift its position during the discharge

FIG. 3.—Lightning—Multiple Flashes.

I have heard very eminent physicists pronounce equally positively for either view. There is no doubt that in many cases the reduplication is due to movement of the camera, or is at least partly due to it; but on June 25, 1891, I was staying in Bath, and during a fine storm about midnight I exposed several plates. In each case the camera was standing on a balcony by itself, and I can conceive of no cause competent to shake it as it was well sheltered from the wind. An enlarged picture of this flash shows its structure. It will be noticed

FIG. 4.—Laboratory Experiment.

that the component flashes are not completely parallel, that there is fainter luminosity connecting the bright flashes, and that this fainter light has a sort of diagonal streaked structure. Altogether it is a very strange object (Fig. 3). But something very like it can easily be obtained in the laboratory (Fig. 4).

A rapid survey of different types of laboratory discharge shows that sparks often tend to reproduce precisely similar twists and turns, and by modifying the conditions under which the discharge takes place we can get the "branched," "straight," "gently undulating," and "crinkled" flashes on a small scale. Still more, we can obtain certain rosy-pink discharges which last an appreciable time, which consist of many sparks and a fairly persistent glow, or which consist of a rapid stream of sparks which may spread over a few seconds in time. Now it is *prima facie*

probable that these other discharges have their analogues in lightning, and surely it is in these reduplicated discharges and their varieties. One question arises, and I think only one, which is, how long does a lightning discharge last? Now my wife and I have repeatedly measured this. The duration of a flash is of course only a small fraction of a second, but during a "discharge" we have been able to watch the movements of a second's hand on a clock while it passed over 3, 4, 5, or in one case even 7 seconds. Suppose, then, the first flash of such a discharge marked out a track of hot or rarefied air, this might be swept along by the wind over a distance of 150 feet in 3 seconds, if that wind reached the velocity of 34 miles an hour, which is by no means an impossible velocity. It is frequently observed in photographs of reduplicated flashes that the various components do not follow absolutely similar paths, and it often occurs that the departure from similarity is near the ground. This is exactly what we should expect if the path of least resistance were swept along as suggested. The movements of the wind are not uniform, and the "path" would frequently get bent or broken, such an event occurring most easily within reach of eddies from the ground.

One more strange puzzle presented by lightning was the mysterious phenomenon of the "black" flash. This is neither the time nor the place to go over all that was said and done on this subject, but I may be allowed to summarise briefly the results of some experiments by which I was enabled to repeat the phenomenon in the laboratory.

On June 6, 1891, a remarkably fine thunderstorm passed over London, and among other photographs I secured one showing this phenomenon. Its characteristic features are that the faint branches are often reversed while the main flash is not, that the reversed flash sometimes shows an unreversed core, and that a "black" flash is sometimes crossed by a bright one. My own negative showed such evidence of over-exposure that it seemed clear that the phenomenon bore some relation to that over-exposure. I found that scores of sparks might be photographed on the same plate without any reversal. But the lightning flash has a white background of cloud my sparks had not, therefore I put a white card behind them, and on exposing to some half-dozen sparks got reversal. This reversal was complete in the case of the weaker sparks, marginal only with more brilliant ones.

This looked as if the action might be cumulative, that is to say, that the addition of the light from the card to that from the spark produced an amount of over-exposure sufficient to bring about reversal. But how about the cases in which a bright flash crosses a dark one? Was it possible that the order of exposure could matter?

It was clearly shown that it did not matter what the source of the reversing light might be. If a plate were first exposed to the images of sparks and then to diffused light, it mattered not at all whether that diffused light were gas-light, lime-light, light from magnesium ribbon, or even the light from some more sparks; reversal took place, and was most complete when the reversing light alone produced a deposit of silver of a density about equal to that which the image of the spark could have produced (Fig. 5).

This also did not look like cumulative action, so the same experiments

were repeated in inverse order, exposing each plate to diffused light first and then to the images of the sparks. The result was no reversal (Fig. 5).

Finally I took a plate, exposed it to the images of a set of sparks, then put some ground glass before the lens and passed about 10 or 12

Fig. 5.

Fig. 6.

sparks, and lastly exposed to the images of some other sparks. On development, where the blur of light due to the diffused light is shown, the first set of sparks give dark images, the second set bright ones (Fig. 7). The phenomena were proved to be photographic only, and they supply a very complete puzzle for the photographic physicist, inasmuch as none of the current theories of photographic action seem to be of much help in attempting to explain them.

Fig. 7.

Mr. Shelford Bidwell, F.R.S., has confirmed these strange results by somewhat different experiments.

I show a pair of photographs showing the reversal and lack of reversal, and a third showing the imitation of the bright flash crossing a dark one.

Cloud Photography.

But I have dwelt too long on the subject of lightning, it is time to pass on to the subject of cloud photography.

In the first place, the photographic study of clouds has for the first time in the history of our science given us the materials for forming a really good atlas of cloud forms. But an atlas implies a recognised system of nomenclature. Every meteorologist has felt that, good as Luke Howard's names may be, they are not nearly enough. A new system is wanted. Now a system of nomenclature to be really satisfactory ought (1) to be based on Luke Howard's, as that holds the field provisionally, (2) to be derived from Greek or Latin words, or it cannot be international, and (3) to have some relation to the mode of formation of the clouds themselves. Unfortunately, we do not yet know enough about the methods of cloud formation, and especially upon the relation between form and

origin, so that many of us feel that the time is not ripe for the establishment of an international system.

However, the International Meteorological Congress have thought otherwise, and it is thanks to photographs of clouds that they have been able to bring out the beautiful and useful Atlas of Clouds. Personally, I feel somewhat sore about that Atlas, because the Committee selected only one English photograph for insertion; and the gentlemen deputed to carry out the work, without any explanation omitted that one. But there is no question about the excellence of the Atlas, whatever we may think of the names adopted. It seems to me a pity that meteorologists should not have waited until we have more precise knowledge of the mode of growth of different forms.

One great step towards a determination of the mode of origin is exact measurements of cloud altitude, especially with a view of showing how far vertical movements are involved in cloud production.

Now cloud altitudes have been measured in several places by two observers making simultaneous determinations from the ends of a base-line. It seems to me wonderful that many such measurements should have been made, because there must be great difficulty in making certain that the two theodolites are really directed to the same point. A great improvement is to substitute cameras mounted like theodolites and photograph the cloud. But this method has its own difficulties, and at Kew, where it was tried under Mr. Whipple's direction, it was soon abandoned in favour of a device whereby the cameras were both pointed to the zenith. A certain number of observations were thus made, and it is a matter for considerable regret that they have been discontinued. Meanwhile, others are busy in the same field, and we are indebted for most of our knowledge of cloud altitudes to America and Sweden.

Some years ago the British Association Committee initiated some photographic determinations at Exeter, employing a novel method of procedure. In the course of a long series of experiments on methods of cloud photography it was found easy to secure good definition of clouds with the sun actually in the field of view.

Two cameras were therefore prepared so arranged that they can be pointed to any part of the sky. Each has a lens of 18 inches focus, and is provided with a shutter which can be released by an electric current. The cameras stand 200 yards apart on a site adjoining the London and South-Western Railway, and are connected by a line of telegraph wire supported in the usual way (Fig. 8).

The mode of operation is very simple. The cameras are adjusted by means of finders so that the sun is approximately in the middle of the field of view. The sky is then watched until some cloud comes near enough to the sun, when the observer at one end presses the contact key, and the exposures are made. At the same moment he notes the time.

Now, owing to the length of the base-line and great length of focus in the cameras, there is appreciable parallax, even with very high clouds. The exact altitude and azimuth of the sun can be calculated from the date and time of day, and this gives us fixed points of reference on the two plates, from which the altitude of the cloud is calculated from the

relative displacement of the cloud image. In this process Mawson and Swan's Photomechanical plates are used, and the exposure is about $\frac{1}{64}$th of a second with an aperture of *f*. 100. But the exposure and aperture may be varied within wide limits without much disadvantage.

It has been objected that the computation is long. This no doubt is true, but it is true of other methods. It has one marked disadvantage

FIG. 8.—Cloud Camera at Exeter.

that it cannot be applied to clouds which hide the sun, nor to those which do not come near enough; but as it is cirrus and cirriform clouds whose altitudes are most important to observe and the sun can be seen through them, the objection is not so great as it would at first sight seem to be. On the other hand, the long focus gives a large image full of minute detail, giving a large displacement for a small angle, and the best opportunity of selecting corresponding points on the two negatives; the image of the sun gives a thoroughly reliable fixed point of reference; the observation of the time is easily made accurately, and is the only precise observation required at the moment; there is no possibility of misunderstanding; the short base diminishes perspective troubles; and last, but not least, the immediate proximity of the sun is the part of the sky in which the thinnest clouds give the most vigorous image.

So far the results have tended to confirm previous observations. There seems to be a steady rise of the various cloud strata, or cloud planes, as the Rev. W. Clement Ley called them, up to about 2 p.m., after which there seems an even more rapid fall. There seems some reason, however, to suspect that cloud altitudes reach a higher level in the west of England than they do in other places where determinations have been made. Thus heights of 5, 6, or 7 miles seem quite frequent with cirriform clouds, while occasionally much greater altitudes have been observed. Thus on June 12, 1896, there were four layers of cloud, cirro-stratus at about 8 miles, upper cirro-stratus at about $9\frac{1}{2}$ miles, cirrus above this, which comes out in three separate determinations, 11·64, 11·45, and 11·2 miles. Still farther up there were some wisps of cirrus which two observations gave as 16·83 and 17·02 miles.

Measurements are still being made when opportunity and possibility coincide.

As to the mere photographic study of cloud forms there has been some difference of opinion as to the best method. I think I have tried all of them except the Nicol's prism. With a slow plate and small aperture and short exposure excellent results can be reached with a little practice and perseverance; and I do not find any advantage from using iso-chromatic plates or yellow screens. The only method which really does seem to have some advantage is the one which was put before this Society in theory a good many years ago by Dr. Riggenbach, viz. the use of some method of extinguishing the polarised component of the blue light of the sky. It is well known that the blue comes from reflection from the minute particles in the air, and that this light is polarised. A Nicol's prism, suitably placed before the lens, may be made to extinguish this part of the sky-light, while the unpolarised white light from the cloud passes through without diminution. The same result is obtained at less cost, and with a larger field of view, by the use of a black mirror placed at the polarising angle.

I have used this latter device a great deal, and believe it to be, on the whole, the most convenient; but it should be borne in mind that the extinction of the polarised light can only be complete along the middle of the view, and that polarisation is only very noticeable in parts of the sky 90° from the sun. As a matter of fact, the black mirror is a great help, even in other parts of the sky where there is little or no polarisation; and my firm belief is that its efficiency is due mainly to a lessening of the brilliancy of the image, whereby only about $\frac{1}{16}$th part of the light reaches the plate, and exposure is therefore about sixteen times as long, and is much more easy to judge. I put on the screen a series of photographs of clouds taken with this little camera. You will see in them an immense amount of fine detail. But for popular and ornamental purposes some people do not like to see the dark background given by a photograph. In nature the gamut of tints is from gleaming white down to the bright blue of the sky. In the photograph we have everything from white to black, whereby the photograph is able to show detail which the eye can never hope to perceive. People have often remarked that they supposed some of my studies were done by moonlight, so I have cast about for a process whereby I could show the sky as blue.

Now I wish to make it quite clear that I have not discovered anything like "colour photography," as it is ordinarily understood; but I have found a process whereby these clouds in their shades of white and gray can be shown on a blue background of sky. The plates are specially prepared, exposed under an ordinary negative, and then developed by suitable chemicals according to the colour required. These pictures, coloured, but free from paint, give more natural effects, but can never show the minute detail which can be shown in the ordinary photograph from its power of exaggeration.

In conclusion, allow me to show you one experiment. Mr. Shelford Bidwell showed a part of it on a previous occasion, but it illustrates well what I have been saying about polarisation. From this lantern on the table a powerful beam of light passes upwards through a large beaker of water, some distance above it is suspended a silvered glass ball, and the lime-light is reflected from this in all directions. Suppose this star of white light to represent the sun, and suppose the cotton wool above it to represent the clouds. Again, suppose the water to represent the atmosphere. It is now clear, and sun and clouds are white.

Pour into the water first a small quantity of hydrochloric acid and then some hyposulphite of soda. Nothing happens at first. The sun and clouds are still white. But slowly the chemical action proceeds, minute particles of sulphur make their appearance, and the beaker begins to glow with a pale blue light which is polarised. As the particles increase in size and number, the sun and clouds get yellower in tinge. After a few minutes the light from the particles is nearly white in colour, is hardly polarised at all, the mimic sun shines of a bright coppery tinge, and the woollen clouds are aglow with the colours of the setting sun.

ANTICYCLONIC SYSTEMS AND THEIR MOVEMENTS.

By MAJOR HERBERT E. RAWSON, R.E., F.R.Met.Soc.

(Plates IV. and V.)

[Read April 20, 1898.]

Cyclones and anticyclones have long been recognised as powerful weather-controllers, and their movements studied, but up to the present very little has been written in this country upon the progressive movements of the cores of the permanent high pressure areas, which are found to be associated with certain localities at different times of the year.

Previous Investigations.

Abercromby in *Weather* has described the weather types due to the relative positions of some of the anticyclonic systems of the northern hemisphere, but it did not come within the scope of his work to describe their movements. In the *Quarterly Weather Reports* of the Meteorological

Office for 1876-80, and again in the *Monthly Weather Reports* for 1884-87, all anticyclones which came within the British area of observation have been tabulated. The form, size, and height of the anticyclone are recorded, where it was first observed, the direction and rate of its motion, the regions passed over, its termination, time under observation, and the accompanying winds and weather. From an examination of these tables it would appear a hopeless task to find any regularity; it is, however, at once apparent that the records make no distinction between one anticyclonic system and another, or between an anticyclone which originated in the Atlantic high pressure area and became merged in the Scandinavian, or one which is due to the Scandinavian, extending to meet the Atlantic area. In consequence, movements have been described as irregular which were in reality distinct movements of two different systems. Synoptic charts, which were subsequently published, and which cover the whole of the area traversed by the anticyclones, leave no doubt upon this point.

Mr. R. H. Scott in a note which is published with the *Report of the Meteorological Council* to the Royal Society for the year ending March 31, 1889, gives the results of an examination of the anticyclones which appear on the *Synchronous Weather Charts of the North Atlantic* for 1882-83 published by the Council. Finding it impracticable to study the movement of the entire high pressure area, he selected the isobar of 30·2 ins. as indicating the regions where pressure was most strongly accentuated. He found that the Atlantic system was constantly being replenished by travelling anticyclonic areas, which drifted slowly from the westward. Fifteen of such areas were traced as advancing from the western portion of America to the central Atlantic during the 13 months, August 1882 to August 1883. None of them occurred between the middle of December and the beginning of March, nor again during May or June. He considers the reason for this to be that during the winter months the belt of readings above 30·2 ins. generally stretched across the Atlantic from Africa to North America; and that during the months of May and June particularly there was hardly a day on which areas of 30·2 ins. showed themselves over the United States. Four of the cases occurred in August, and three in October, or nearly 50 per cent of the whole in these two months. It is an important fact that motion of the nature indicated was clearly traced to certain months only of the year, but it will be seen hereafter that it is not the case, as seems to have been inferred, that there is a general tendency throughout the year for anticyclones from America to replenish the Atlantic system, and that the reasons for not finding any cases at certain times of the year are very different from those indicated.

In America, Loomis devoted a great deal of attention, prior to 1885, to the movements of anticyclones in the northern hemisphere, and we have the results in his *Contributions to Meteorology*. With infinite labour he studied, as he tells us, the weather maps of the American Signal Service from November 1871 to 1884, Hoffmeyer's *Cartes Synoptiques Journalières* from December 1873 to November 1876, which were carried on, up to the time of his writing in 1884, under the joint supervision of the Danish and Hamburg Meteorological Offices; as well as the maps of the *Bulletin International* from October 1877 to June 1884. The

language with which he concludes his investigations might well make us despair of ever tracing any regularity in the movements of anticyclonic systems. After saying that areas of low pressure seem to be endowed with a power of locomotion which resides within themselves, he proceeds: "Areas of high pressure exhibit no such power. Their low temperature creates a tendency to crowd towards a warmer region; and this tendency is obscurely seen in the high areas of Europe and Asia. It is more distinctly seen in the high areas of the United States, probably on account of the proximity of a much higher temperature, viz. the Gulf of Mexico on the south, and the Atlantic Ocean with the Gulf Stream on the east. Aside from this cause, the movement of areas of high pressure seems to depend entirely upon external forces. A neighbouring area of low pressure may draw off the air from one side, and thereby cause a displacement of the centre of maximum pressure; or the high area may be re-enforced at the top in such a manner as to cause a rapid movement of the centre of maximum pressure, *in a direction and with a velocity which are apparently subject to no law.*"[1]

Fortunately the progress of meteorological science since 1884 has been such as to bid us hope that the difficulties attending this complicated subject are not insurmountable. We are already able to see that the method which he followed in his investigations was responsible for his failing to find any law governing the motion of high pressure areas, and for his obtaining such indefinite results. Take as an example the way in which he deals with the high areas which he found in the charts over Europe and Asia. He tabulates all the cases from October 1877 to June 1884 in which the charts showed an isobar of 31·0 ins., and finds that out of 74 cases, 27 occurred in January, 1 in February, 5 in March, 1 in October, 8 in November, and 32 in December; that is, nearly 80 per cent occurred in December and January; and that out of 14 occasions in which the pressure of 31·0 ins. was maintained for at least two days in succession, the centre apparently made no progress in 8 of them; in 3 there was a slight movement towards the east, in 3 a slight movement towards the west, in 2 towards the north, and in 4 towards the south. In all his investigations he adopts the method of selecting an isobar, and analysing all the cases in which such an isobar appears on the chart. He obtains in nearly every case equally inconclusive results as the above, and he infers in consequence that the centre of high areas in Europe and Asia has no decided progressive movement, though it vibrates to and fro from day to day. But such a method cannot give any correct result when high pressure areas vary in their height, as we know they do, from month to month, and when their movements only fall within the analysis during one season of the year. It must fail altogether to trace any progressive movement, if the height of the anticyclone falls below the isobar selected, as it moves away to another region. Moreover it cannot succeed if the method leads to two different systems, with distinct progressive motions of their own, being tabulated together. All that Loomis has shown in the example quoted is that pressures above 31·0 ins. occur most frequently in December and January over Europe and Asia; and that the centre of the high area is far to the east of Europe.

[1] Loomis's *Contributions to Meteorology*, Revised Edition, 1885.

Extent of the Present Investigation.

The object of this paper is to show that if the various anticyclonic systems are considered separately and their movements investigated continuously throughout the year, their cores will be found to have a distinctly marked progressive motion, and an attempt will be made to trace this in detail in the case of those systems which affect the weather of the British Isles. The view taken throughout this paper is that the movement of a high pressure system is to be gathered from that of its core. The system may extend in any direction or remain stationary as a whole, with its core vibrating to and fro, or drifting slowly with somewhat irregular motion; but the progressive movement of the system is defined by the mean positions of the core, as plotted on a chart from month to month.[1]

It is not an uncommon mistake to imagine that two continuous high pressure belts are maintained round the globe throughout the year, covering the regions 30° to 40° approximately north and south of the equator. It has even been supposed possible that an anticyclone might make a complete circuit of the belt in the southern hemisphere without being broken up, if it were not for the Andes range. But let us consider for a moment what is the actual disposition of the various high pressure areas which constitute the two belts, and the way in which they are displaced in summer from the positions they occupy in winter.

High Pressure Areas of the Globe.

In the southern hemisphere a well-defined system is always found n the Pacific off the west coast of Chili; another is off the west coast of Cape Colony, and another is in the South Indian Ocean. In the northern hemisphere there is a system in the North Pacific which ersists throughout the year; another over the Atlantic for about ten nonths of the year; while two systems over the United States and ver Central Asia respectively make up the northern belt for about ix months of the year. But though the term "belts" has been applied o this succession of high pressure areas which surround the globe, it is nly a fairly accurate description in the case of the southern hemiphere, and is not at all applicable to the series of high pressure systems orth of the equator, which are incessantly changing their positions, and hich in certain months are entirely displaced by systems of low ressure.

Movements of Systems in the Southern Hemisphere.

Owing to the almost unbroken stretch of water, only interrupted by ustralia, South America and the Cape, the movements of the systems omposing the southern belt are followed much more easily than those f the northern, where the water is surrounded by vast areas of land. n the southern hemisphere we find that the belt migrates north as a hole, with the sun from April to June, and that the centres of the ystems themselves are displaced from month to month in both easterly nd westerly directions. During April and May the Australian system

[1] The term "core" is applied throughout, in a popular sense, to the area where pressure is ighest.

moves westwards to the African coast, while the Pacific and Atlantic systems move eastwards. The progressive movement in either direction is very gradual. As the temperature falls, important secondary centres appear over each of the land areas, and their height increases, reaching a maximum in July in the case of the secondary Australian core. This latter moves off the land eastwards in October and November, and becomes merged with the Pacific system in December, while the primary Australian system during the same months returns from Africa to its summer eastern position off the west coast. It is noticeable that the progressive movement eastwards of both systems in October is very rapid. From November to February areas of low pressure form over the continents and greatly contract the belt of high pressure. It is unnecessary to go further into the movements of this belt, but the above throw considerable light upon the less easily followed movements of the high areas composing the northern belt. First we see how important it is to distinguish one system from another, and also the movements during one period of the year from those during another. The progressive movement is not always easterly. High pressure areas leave the land as temperature increases, and give place to low. When the temperature falls low enough high pressure areas are formed over the land as secondary systems, the main system persisting in the locality it usually dominates. This is very noticeable in the case of the secondary system which forms over Australia, while the Australian system itself moves westwards away from the land. In the southern hemisphere one principle seems to govern both the formation and the movements of the various anticyclonic systems, namely, *wherever strong contrasts of temperature are set up, atmospheric conditions result which give rise to anticyclonic systems and largely control their movements.* What these conditions are, how they act and at what levels, are questions which it is beside our present purpose to inquire into. But that the above general principle prevails, any one may satisfy himself who will study Buchan's[1] charts of the isobars and isotherms of the southern hemisphere.

Movements of Systems in the Northern Hemisphere.

When we turn to the northern hemisphere, the movements of the anticyclonic systems are seen to be more complicated and more difficult to follow. The mass of daily synoptic charts, which often appear to conflict with one another, adds to our difficulties. To one who is accustomed to read contoured maps of countries, such charts present day by day an ever-shifting scene of mountain peaks and valleys. It is as if a traveller were looking out upon mountain ranges, whose peaks were constantly appearing and disappearing, and the trend of whose valleys was incessantly altering. Where elevated land was seen one day, a low-lying country with depressions of some magnitude might be seen the next. So rapid are the changes, and apparently so anomalous, that sometimes it seems hopeless to identify the high areas which are seen on one chart with those which appear in quite different localities on another. And the simile of mountain ranges and valleys is found to

[1] Buchan's series of Charts of Mean Monthly Temperature and Pressure accompanying the *Report of the Voyage of H.M.S. Challenger*, 1889.

express very inadequately what appears on the charts. Rather is it as if a wave were in constant motion, with certain points where the crest was elevated into, sometimes one, and sometimes several heads or peaks, which never retain the same positions, and which sink with the wave to appear in an altogether new locality. Where the crest of the wave had been, there is now a hollow, with whirling eddies which may soon acquire great violence. This picture is more like what the charts present, and the idea will be still more accurate if, in imagination, we can see waves of compression and rarefaction with centres of energy which are being incessantly displaced. Over the North Pacific and Atlantic Oceans the daily charts reveal areas of high pressure which never entirely disappear, but whose cores are never stationary for long at a time. Over the land areas, however, anticyclonic systems can only be traced during certain months of the year, and at some seasons they will appear and disappear in a way which suggests a rising and falling wave. But in all their movements, whether over the ocean or over the land, there is always a progressive motion in some direction or another, and the lessons learnt from following the systems in the southern hemisphere enable us to trace in the northern what this direction is. High pressure areas in that hemisphere, it will be remembered, move off the land as temperature increases and return to it, or form over it, as temperature falls; and this important law can be seen governing the daily movements of anticyclonic systems in the northern hemisphere in spite of all the complexities which arise.

Suggested Explanation of the Movements.

Perhaps it will make what follows clearer, if I first give the result of my investigations, and then support it by analysing the movements of the various systems, in the course of which I shall deal especially with the movements of those which affect the weather of the British Isles. The solution lies in the correct interpretation of Buchan's isobaric charts already alluded to, which show the mean monthly pressure over the northern hemisphere during the 15 years, 1870-84. A high pressure area is there seen to persist throughout the year off the west coast of California, and its centre to be displaced but slightly from a mean central position. Another high area is found for ten months over the North Atlantic, but its position over the west of Europe during January and February might be difficult to identify, were it not for what we have seen taking place in the southern hemisphere when the temperature fell over the land, and the core of an adjacent system moved on to it. The same thing occurs with this Atlantic anticyclonic system. Over the United States and over Central Asia, on the southern borders of Siberia, two high areas are found during January and February near the parallel of 40°, which move north during March and are not seen again in these regions till September. They can be easily identified over the land during the remaining months of the year.

The American and Siberian Systems move far North.

For what becomes of these two systems from April to August we must again turn to the information afforded by the systems in the southern hemisphere. We saw there that the important system which

persists over Australia during the southern winter moved away from land as temperature increased, and became merged with the Pacific high pressure area off the west coast of Chili. No doubt the same thing occurs in the case of the American and Siberian systems. Throughout the winter they have been in contact across the Arctic regions, and have been the cause of the prevailing high pressure there; and as the increasing influence of the sun begins to be felt and summer approaches, they leave the land and persist together over the Arctic regions. The course of the American system can be followed on Buchan's charts better than that of the Siberian, but no one who studies the daily charts of the Danish series can doubt that the important system which is seen to traverse western Russia and Scandinavia, with a progressive north-westerly movement in the spring, and a south-easterly movement in the autumn, is any other than the European portion of the Siberian system, and that the course it follows is a true indication of the direction in which the Siberian system is moving. Pressure over the Polar regions reaches its annual maximum in April, and though it steadily diminishes for the next three months, it is always greater there than in the regions a little south. It is a significant fact that in Buchan's charts a core of high pressure reappears in August over northern Spitzbergen on about the meridian of Greenwich, and that the return of the Scandinavian high pressure area can be distinctly traced on the daily charts in the following month. The conclusion is therefore irresistible, that when the northern belt of high pressure migrates north as a whole with the sun, the high pressure areas which dominate the United States and Central Asia during the coldest months of the year, move to the Polar regions and merge themselves in the permanent area there.

Monthly Movements.

As Buchan's charts are not accessible to every one, I give in Fig. 1 (Plate 4) the mean monthly positions of the centres of the various systems which have been identified. The number of the month is added to the identification letter of the system, and where no core can be plotted on the diagram, the direction in which the core would probably be found, if sufficient observations were available, is indicated by an arrow with its head at the most southern parallel to which the maximum isobar extends. In Table 1 I give for each month the latitude and longitude of the centre of each system, its highest isobar and the comparative size of the oval or circular core included in the central isobar. In January and February the centres of the Siberian (S) and American (N) systems are found in Fig. 1 on nearly the same parallel of 43°, and are 102° to 104° east and west respectively of Greenwich, with the Atlantic (A) system occupying a central position between them. Away to the west, and somewhat to the south, lies the Pacific (P) system. All three move west during March, those over the land moving further north as well, while those over the oceans move a little south. The subsequent movements of the Atlantic and Pacific systems are better traced by reference to the Table, which must be interpreted as indicating the mean monthly position of the respective cores during the years 1870-84. The great displacement eastwards of the Atlantic core in September, and of the Pacific core in October, is similar to what we saw taking place in the southern hemi-

MEAN MONTHLY POSITIONS (I TO XII.) OF THE CORES OF THE SIBERIAN (S), AMERICAN (N), GREENLAND (C), ATLANTIC (A), AND PACIFIC (P), ANTICYCLONIC SYSTEMS, 1870-84.

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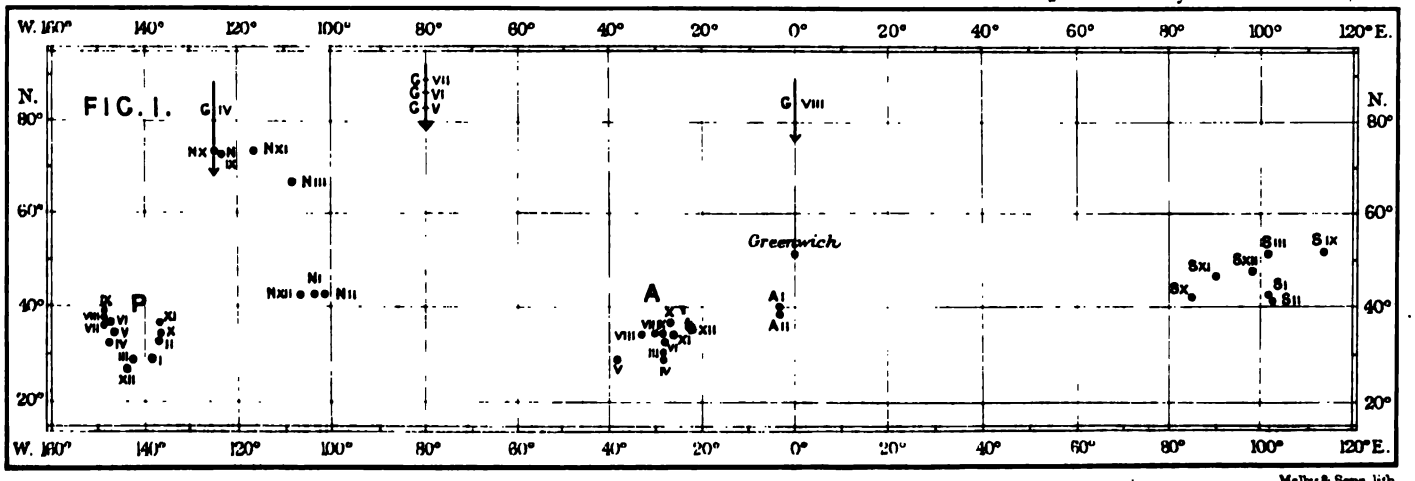

Malby & Sons, lith.

SIBERIAN.												
Lat. of centre	42°30′	42° 0′	50°10′	...	...	...	...	...	52° 0′	41°30′	46° 0′	47°30′
Long. ,,	102° 0′ E.	103° 0′ E.	100°45′ E.	...	...	...	...	...	113° 0′ E.	85° 0′ E.	90° 0′ E.	98° 0′ E.
Highest Isobar	30·50 in.	30·50 in.	30·20 in.	...	...	...	...	...	30·00 in.	30·20 in.	30·40 in.	30·50 in.
Size of Core .	small.[1]	small.[1]	large.	...	...	...	...	...	medium.	large.	medium.	small.
AMERICAN.												
Lat. of centre	43° 0′	43° 0′	67° 0′	...	...	...	...	...	74° 0′	74° 0′	74° 0′	42°30′
Long. ,,	104° 0′ W.	102° 0′ W.	109° 0′ W.	...	...	...	...	...	123° 0′ W.	125° 0′ W.	117° 0′ W.	107° 0′ W.
Highest Isobar	30·20 in.	30·10 in.	30·10 in.	...	...	...	...	...	29·95 in.	30·00 in.	30·10 in.	30·20 in.
Size of Core .	small.	large.	large.	...	...	...	...	...	medium.	medium.	small.	small.
GREENLAND.												
Lat. of centre	...	...	...	80° (over)	80° (over)	80° (over)	80° (over)	80° (over)	...	...	...	...
Long. ,,	...	...	...	125° 0′ W.	80° 0′ W.	80° 0′ W.	80° 0′ W.	0° 0′	...	...	...	...
Highest Isobar	...	...	...	30·15 in.	30·10 in.	29·95 in.	29·90 in.	29·95 in.	...	...	...	...
Size of Core .	...	...	...	medium.	medium.	large.	large.	small.	...	...	...	...
ATLANTIC.												
Lat. of centre	40° 0′	39°40′	30° 0′	29°50′	29°40′	31° 0′	34°30′	34° 0′	34°30′	36° 0′	34°30′	35° 0′
Long. ,,	4° 0′ W.	4° 0′ W.	28° 0′ W.	28° 0′ W.	38° 0′ W.	28° 0′ W.	30° 0′ W.	33° 0′ W.	29°30′ W.	27° 0′ W.	27° 0′ W.	22° 0′ W.
Highest Isobar	30·20 in.	30·15 in.	30·10 in.	30·10 in.	30·15 in.	30·20 in.	30·20 in.	30·15 in.	30·15 in.	30·15 in.	30·10 in.	30·15 in.
Size of Core .	small.	small.	small.	small.	small.	small.	small.	small.	small.	small.[2]	small.[2]	small.[2]
PACIFIC.												
Lat. of centre	28° 0′	32°30′	28° 0′	32° 0′	34° 0′	36° 0′	35°30′	39° 0′	39°30′	33° 0′	35°30′	26° 0′
Long. ,,	139° 0′ W.	137° 0′ W.	142°30′ W.	147° 0′ W.	146° 0′ W.	148° 0′ W.	148°30′ W.	149° 0′ W.	149° 0′ W.	136° 0′ W.	137° 0′ W.	144° 0′ W.
Highest Isobar	30·15 in.	30·20 in.	30·25 in.	30·30 in.	30·30 in.	30·30 in.	30·30 in.	30·30 in.	30·30 in.	30·15 in.	30·20 in.	30·20 in.
Size of Core .	small.	small.	small.	small.	small.	small.	small.	small.	small.	small.[3]	small.	small.

[1] In January and February a second core appears north-west of the Black Sea, and forms part of this system.
[2] In October, November, and December there is a second core belonging to this system over the Mediterranean.
[3] In October a second core belonging to this system is over the Alleghany Mountains south-west of Washington, and is further west in November.

sphere *at the same time of year*. We also see the formation of a second core over the land as temperature falls in both America and Europe, which, in the case of the former, becomes completely merged in the American system in December.

From April to August the Siberian and American systems are seen by the Table to lose their identity, while the Greenland (G) system becomes prominent. The importance of recognising this system will appear when the daily charts come to be studied, and its influence will be found to explain much that has hitherto been obscure in the movements of anticyclones during these months. The annual minimum in these regions is reached in July, but the pressure there is greater than anything that is to be found in more southern latitudes. With the reappearance of a core of high pressure in August over north Spitzbergen, the American and Siberian systems separate, and from September onwards move steadily to their winter positions. The identification of the Scandinavian system with that of Greenland in August, and with that of Siberia in September, is fully confirmed by the daily charts of the Danish series. In January and February, as we shall see, it often forms a separate system over Central Europe, to the north-west of the Black Sea, and it appears in consequence in Buchan's charts for those months as a second core belonging to the Siberian system. Table 1 interprets Fig. 1, and shows in addition the way in which the several cores increase and decrease in height from month to month.

The Influence of Locality.

It is a peculiar feature of the Atlantic and Pacific cores to be small throughout the year, and on examining into the cause of this an important fact was observed. The *Synchronous Weather Charts of the North Atlantic* from August 1882 to September 1883 enable us to follow all the movements of the Atlantic system and the drifting of its core. The core is found to be seldom stationary, and to be incessantly changing in height. But there are certain localities where, if it expands in size, while remaining stationary, the pressure falls, and the same thing happens if it moves away; while if it moves towards what proves to be the position of maximum pressure for the period, it contracts in size and pressure increases. To some extent this is seen in each month that the core is over the Atlantic, but the following instances are particularly easy to follow:—From April 9 to 13, 1883, the core increases in height and contracts in size, as it moves to a certain locality, and the pressure there reaches the maximum for the month; during the 14th and 15th, as the core expands and is displaced, pressure falls. By the 30th the core has returned to the same position it was in on the 13th, it is again small and its height is again much the same. During the three periods May 9 to 15, 16 to 19, and 20 to 29, we see a repetition of the same thing. What the full significance of this is, what bearing it has upon the formation and maintenance of anticylonic systems, and whether or not there is any periodicity such as would explain Buchan's six Cold periods over Scotland for instance—are questions outside our present inquiry. Table I. must at all events be interpreted in accordance with it. We conclude that over the Pacific and Atlantic oceans there is, in certain months, a particular locality of comparatively small area over

which the centre of maximum pressure persists, and that when the core moves away from it or expands to any size, it diminishes in height. It may be that high pressure is to be found elsewhere, but this will occur so seldom, and for so short a period, that it will not be traceable on an isobaric chart of the mean pressure for the month, and in consequence no core will appear there. We are not to understand from Table I. that the cores of these systems were as a rule restricted to a particular locality each month, nor that the high pressure systems as a whole had no daily progressive movement. In the case of the Siberian and American systems when over the land, it is noticeable that the cores are only small during the colder months, when the systems are more stationary than at other times; and that as they move to and from their winter positions, their cores are large. This is because they are considerably displaced in successive years from a mean monthly position, and in consequence they cover a large extent of country on these charts.

Facts recorded by previous Investigators.

At this point it will be well to test the conclusions that have been arrived at by seeing whether they are confirmed by the facts recorded by previous investigators, and whether they afford any explanation of the inconclusive results that were obtained. Loomis, as we have seen, analysed all the instances he could find, during seven years, of a high pressure system of 31·0 ins. and upwards, covering Europe or Asia. By adopting such a system of analysis Fig. 1 and Table I. now make it clear that he could not have obtained any results than those which he got, viz. that all the cases occurred between October and March, and that 80 per cent were in December and January. Nor are we surprised that he found several instances of the centre remaining stationary, and that when a progressive movement could be traced, it was pretty equal in all directions. In this case his method of procedure limited his investigations to those months of the year during which the Siberian system is increasing in height as it moves to the position it takes up in January, when the season of maximum cold to be found on the face of the globe is occurring just to the north-west; and to the period when it moves back again from that position, decreasing in height as it does so. In January and February, Table I. shows that the mean height is very steady, and has risen to the annual maximum, which accounts for the high pressure he found there. The displacement of the core is also very small, as we see by its latitude and longitude in the Table during those two months. The longitudes only differ by 2 degrees and the latitudes by 30 minutes. Hence his conclusion that high areas, generally, had no movement. The cores are also small, according to the Table, in both months. Fig. 1 and Table I. are in complete agreement with Loomis's facts, and offer a satisfactory explanation of the results which he obtained.

In another instance he analysed all the cases over the same region in which the slightly lower pressure of 30·9 ins. was found. Again, they all occurred in the period from October to March, and in the far east. Three-fourths of them were over Asia. He also noticed that only those cases in which the pressure was under 31·0 ins. occurred farther north than lat. 60°, instances of a pressure of 31·0 ins. and upwards

being confined to more southerly latitudes. This is another confirmation of our conclusion that when the Siberian system is being lowered by the increasing heat of the sun it is also being driven north off the land.

Loomis makes another analysis of the cases over the United States and Canada, in which the barometer at any observing station rose above 30·85 ins. during the years 1872-84. He tabulates fifty-two different areas of high pressure distributed among the months as follows:

October, 1 case	December, 8 cases	February, 16 cases
November, 10 cases	January, 14 ,,	March, 3 ,,

They are all embraced within a period of less than five months from October 26 to March 12. By tracking the systems as long as a pressure of 30·50 ins. was maintained, he found that the average course of the centres of these areas, measured in a straight line from its first to its last observed position, was towards south-east; that areas of extremely high pressure came down from the north, and in some cases increased in height after crossing the parallel of 49°. Loomis had specially in view the movements of the high pressure areas, and reading his results with the assistance of Table I. we see that they mutually confirm one another. It is very instructive that by adopting the height of 30·85 ins. for his investigations he happened to analyse the period when the American system is returning from the north to its winter position over the United States, and eliminated the greater portion of March and the whole of April, when Table I. tells us it is moving north off the land to the Polar regions.

The Meteorological Weather Reports already referred to for the eight years 1876-80 and 1884-86, record the movements within the British area of 217 anticyclones. I have only been able to identify 75 of them with the Scandinavian system. They are spread over all the months of the year except July, in which month none can be identified. Almost 50 per cent of the cases show a movement in an east, south-east, or south direction; 12 per cent show a movement north or north-east; while out of 13 cases in which a westerly movement is recorded, 10 occurred in April, May, or June, 1 in November, and 2 in December. The comparatively small number which can be traced to the Scandinavian system, and the westerly movement in April, May, and June are noteworthy. These results in no way contradict the interpretation which has been put upon Fig. 1, and the westerly movement lends great confirmation to it.

Finally, we have Mr. Scott's analysis of the North Atlantic Charts, 1882-83, in which he found that travelling anticyclonic areas drifted to the central Atlantic from the western parts of America, but that such cases were principally confined to August and October, and that no cases occurred from the middle of December to the beginning of March, nor during May or June. I see in these results a valuable testimony to the truth of the views I have ventured to express with regard to the meaning of Table I. During the winter months, when temperature over Canada and the United States is decreasing, the American system is moving to a position somewhat south of the region of greatest cold, and here it remains comparatively stationary during January and February. I

March it begins to move north. The whole tendency of high pressure areas from the middle of December to the end of February will be to remain on the land, and it will only be with the return of higher temperatures that they will move oceanwards. In May and June Table I. indicates a northerly movement of the Pacific system, which is also distinctly seen in the month of June to occur over the Atlantic, and if we consult the daily charts for May we shall see that during the eleven years, 1881-91, almost without exception, there is a marked tendency for the Atlantic system to extend north to meet the Greenland system, which is by this time well established. The reason given by Mr. Scott for no anticyclones drifting from America into the central Atlantic during May and June is a secondary one. I think that indicated by Table I. is the primary cause, viz. the atmospheric conditions which foster high areas and control their movements now exist far north and are drawing systems northwards.

With August begins the decline of the sun's influence on the northern hemisphere, and the land will show this in a more marked degree than the ocean. Where sufficiently great contrasts of temperature arise, owing to the presence of large lakes for example, anticyclones will be formed, and their progressive movement will follow the same law as is seen to hold with the permanent systems; they will move to those regions where suitable contrasts of temperature exist. Such regions are pointed out to us by the permanent systems. In August the Atlantic system, according to Table I., is well to the west, over the central Atlantic, and to this region all anticyclones formed over America will move more readily than to any other. I see many reasons for believing that the general easterly circulation of the upper atmosphere has considerable influence upon the movements of anticyclones, and once the return east of the Atlantic system as a whole sets in, which takes place about August, instances of anticyclones travelling east continuously for great distances before being broken up are frequently seen. This is very noticeable in all years during October, when they can be traced across the Atlantic for eight or nine successive days. I have not found any such continuous movement from March to August as appears to exist from the middle of August to the end of February. It may be conceded then that the facts pointed out by Mr. Scott, like those given by Prof. Loomis and recorded by the Meteorological Office, are all readily explained by Table I. and Fig. 1, and that there is nothing contradictory in any of them of the views that have been advanced.

Method of Investigation.

The solution which I have submitted was the result of an examination of all the available synoptic weather charts. The same method of plotting the cores was followed as in the case of Fig. 1. The charts were grouped in periods to which they seemed to lend themselves; they were studied till secondary cores and their movements could be distinguished from the one or perhaps two principal heads and their movements, as well as from the progressive movement of the system as a whole; these and other details were written down, and very soon the charts themselves became so familiar that any great departure in any

year from the mean was recognisable at once. It became evident that certain features recurred; systems extended towards one another, their cores drifted and merged into one another, or a system would at some particular season disappear altogether from a locality in which it was generally to be found. Then it was observed that the set or drift of the systems was the same on the whole, and at certain times of the year was very pronounced. Sometimes it almost appeared as if the Scandinavian, Atlantic, and American cores were so related to one another that each would move as if rigidly bound to the others; as if in very fact they were whirls upon the crests of three waves, and that the waves rolled on, or rose and fell under the same external influence.

In order to show these movements without entering into too great detail, I have selected out of the numerous Weather Charts those for 1881-91, compiled by the united Danish and German Meteorological Offices. This series has the advantage of a monthly chart, and in Figs. 2 to 11 (Plate 5) I have plotted the centres of the systems whenever they are to be traced. When they are not visible, but their probable positions can be inferred, these are shown by lines, with arrow heads to mark the highest isobar, as in Fig. 1. If a core has remained long enough over two different districts to leave its trace in both positions on a chart, both are plotted, but the one which is farthest from the mean monthly centre of the system is enclosed in brackets. Secondary cores are omitted. The Scandinavian system is given the same identifying letter (S) as the Siberian in Fig. 1, of which it forms a part. It is impossible without complicating the figures to indicate whether the core is a large or small one, whether its height is above or below the monthly mean given in Table I., and what the localities are which are most frequented. These questions are all of supreme interest, but it is necessary to leave them, and many others which suggest themselves, out of consideration. There is no figure illustrating the year 1883, and the last four months of 1882 are missing from Fig. 3, this series of weather maps having been discontinued during the period that the North Atlantic was being mapped by our Meteorological Office.

Analysis of Movements, 1881-91.

An examination of Figs. 2 to 11 (Plate 5) shows that the Atlantic system has a distinct movement westwards off the land in the early months of the year, and eastwards on to it in the later months, being found persisting over Europe in some years by November, and in most years, if the daily charts are consulted, as early as October. The Scandinavian system is often found far east, merged most probably in the Siberian, and this is confined altogether to the early and late months of the year. Its progressive movement westward in spring, its disappearance from land in summer, and its return in September, can be traced in several years. The formation of a distinct high pressure area over Greenland and its vicinity in summer, and the instances of the Scandinavian system being tracked to these regions then, occur too frequently to leave any doubt that this is where the latter system is driven to by high temperature.

1881 (Fig 2).—The core of the Atlantic system is not defined on the January chart, but from the daily maps it is seen to be far south as a rule, and to move

north on one occasion over the British Isles. In February, March, and April it is displaced west over the ocean, reaching its most southerly and westerly position for the year in March. During May the system extends north to meet the Greenland system, and its core is seen to drift south-west after they have merged. From June to September the extension north is frequently repeated, and the British Isles are then covered by high pressure. In October it moves landwards towards Europe, and on three occasions the core is found over these islands. Its continuous drift eastwards across the Atlantic for 9 days is very noticeable. In November its mean position is over the Iberian Peninsula, and in December close to Madeira.

The Scandinavian system is far east during January, and moves north-west in the following month, leaving a record of its core in two localities during the month. Its core cannot be traced on the chart for March, but it reappears far west in April. In May and June, though far north, the system can still be distinguished by the movements of its core, and we feel convinced that we are following the same system as in April. It returns to land in September, and its slow general drift east and south from Scandinavia to Central Europe and to Russia is noticeable in this and the three following months, though owing to its movement the core is not to be seen after September on the monthly charts, and we must turn to the daily maps for the purpose of tracing it.

The year 1881 was exceptional for the Greenland system extending much farther south than usual in January and February, and on one occasion in January a core from this system moved as far south as the British Isles. This occurred again in January 1891, and on both occasions the core continued its drift south or south-east, but in 1881, only, was high pressure pushed down so continuously onto the Atlantic during these months.

With the mean positions of all the different systems before us, it is instructive to examine the cores which appear over any district, and to trace their origin and general motion. Take, for example, all that passed over the British Isles at any time during the year, omitting, as before, those that were only subsidiary. There were 19 occasions on which a core was over these islands from 1 to 6 days. They occurred in all the months except February and November, and with 3 exceptions were the result of one or other of the systems extending in our direction and its core drifting from its mean position over us. Thirteen were due to the Atlantic system and 3 to the Greenland. The 3 exceptional cases occurred after the Atlantic and Scandinavian systems had extended across an area and had merged. There is never any difficulty in determining the system to which such a core belongs, and to whose movements it conforms.

An analysis of some of the individual movements of the systems is strongly confirmatory of the views that have been advanced. In February a slow drifting westwards across Russia of the core of the Scandinavian system occurs. In June, August, and September there are several instances of the Atlantic system extending north to Iceland and covering the British Isles with high pressure. In September an area of high pressure forms over Iceland, and drifts slowly east on to the land, where it persists for a time. Exactly the same drift may be traced in the previous April; but instead of persisting on the land, the core returns to Iceland, as at that time of year high pressure areas are being driven off the land. Both systems are readily identified with the Scandinavian, and the movements are just what we might expect.

1882 (Fig. 3).—The core of the Atlantic system is over the land in January, and the system moves out on to the ocean in February without persisting long enough in any locality for its core to become visible in the monthly chart. In the three following months the movement is westerly and somewhat southerly, after which the system migrates north.

The Scandinavian system is far east during the early months, and its core is not defined in April, though it can be traced on the daily maps moving westwards over Northern Europe. Its core is just to the east of the British Isles in May, the system not moving to the far north till later. This can be traced on the daily maps during June, till it takes up a mean position somewhat north of lat. 70°. Supplementing the information in the Danish charts with that given in the daily maps of the North Atlantic, the Scandinavian system returns to land in September, and the Atlantic system begins to hug the African coast after October 10, and to maintain its core frequently over Spain and Western Europe in November.[1]

There were 7 occasions in 1882 of the core of the Atlantic, 5 of the Scandinavian system, and 6 of both combined, being over the British Isles. The Greenland core never came so far south. The instances of the two systems named extending to meet and merge with one another, and of a core moving over these islands subsequently, were very frequent. In all such cases I see no evidences of systems travelling to replenish one another, but rather of their being drawn from the positions which the season of the year determines for them, to a locality where the conditions temporarily favour a maximum pressure. When these conditions are relaxed, the seasonal influence reasserts itself, and the systems return to their normal positions.

1883.—For eight months of this year we have the magnificent daily synchronous charts of the North Atlantic. Details of the movements of the Atlantic, Scandinavian, and American systems will be found in Appendix I. In January and February the Atlantic system is either over Western Europe or not far from land, while the core of the Scandinavian which can be traced in Central Russia in January moves eastwards off the charts in February. In March the Atlantic system shows a progressive westerly movement which takes it off the land, while the Scandinavian is also leaving the land and moving towards Greenland. From April to July the Atlantic system is over the ocean, migrating farther north in May than in any previous month, and the Scandinavian continues far north, though once its core is found early in June as far south as the British Isles. In August the movement south of both systems can be traced. Until December, when the Danish series recommences, we are without charts.

During these nine months there were 12 occasions when a core was over these islands, on 11 of these it belonged to the Atlantic system and on only 1 to the Siberian.

1884 (Fig. 4).—Notice the very westerly positions of the Atlantic system in February, August, and November of this year, and the non-return, except during a short time in November, of this system to land, though its tendency to do so can be traced in the daily charts after the middle of October. As usual in this month a slow drifting of its core takes place across the Atlantic, occupying 9 days on one occasion. The core of the Scandinavian system which has been far east in January and February appears in March, and moves still farther west in April. It can be traced in May joined with the Greenland system and remains merged with it till August when it moves south, and can be identified drifting from the north of Scandinavia. There are 17 occasions when a core is found over the British Isles. In 8 cases this was due to the extension of the Atlantic system over us, in 7 to that of the Scandinavian, while once it was due to the two systems combined, and once to the Greenland high pressure area.

[1] Incidentally I may call attention to the reappearance in these charts of the core of the American system to the west of Greenland after October 30, which moves south towards the Canadian chain of lakes, and then steadily east towards Newfoundland, confirming what has been said about the return of this system from far north.

1885 (Fig. 5).—The westerly position of the Atlantic system continues uring January and February of this year. The core does not appear in the ıtter month, but from the daily charts it is known to be over the Atlantic and ır south. The Scandinavian system is far east and has no core visible on the ıarts for the early months, but, as in the case of the Atlantic system, there re several indications that it moved east and north from January to April, fter which it went far north. Both systems suggest the idea that the unusual ıovements this year were a continuation of those of last year, and that the on-return of the Atlantic system to land last winter and its westerly position ıis spring are connected with atmospheric conditions affecting the land as well ; the ocean. In support of this we find that the Scandinavian system does ot return to land till October this year, nor the Atlantic till November, which ı later than usual. Some influence continues to keep the systems over the ean and away from their normal positions on land.

There were 19 instances during the year of a core being over the British sles, 17 of which were due to the Atlantic system moving over our area, 1 to ıe combined movement of this and the Scandinavian, and 1 to that of the reenland system.

1886 (Fig. 6).—It seems almost certain that the same conditions which ave prevailed since 1884 are still in operation to keep both the Atlantic and candinavian systems far west. The westerly position of the latter in January nd its gradual and small displacement west during the next three months is articularly noticeable, while the Atlantic system, during the later months, is gain far west.

On 16 occasions the core of a system was over the British Isles ; on 13 it as the core of the Atlantic, on 1 the core of the Scandinavian, and on 2 ccasions the core of the combined Atlantic and Scandinavian systems. The reponderance of cases in which the core over these islands is traceable to the tlantic system is beginning to be very marked.

1887 (Fig. 7).—Again notice that the non-return of the Atlantic system to ınd in December last year is followed by this system being far west in January nd February, while the Scandinavian system in these months is also much ırther west than usual. We find no trace of the Scandinavian core on these ıarts in the last half of the year, but in the daily charts it is seen to return to ınd about the usual time, and to exhibit the same slow southerly drift from ıe north of Scandinavia in September till it ultimately merges in the Siberian stem far east. The Atlantic core returns to land in October and remains ıere sufficiently during December to leave its trace on the chart.

On 33 occasions a core was over the British Isles ; 18 were due to the tlantic, 10 to the Scandinavian, 2 to these two systems combined, and 3 to ıe Greenland system. The positions of the Scandinavian core in February, [arch, and June led to 7 of the 10 cases occurring in these three months.

1888 (Fig. 8).—The core of the Atlantic system, which was seen to be over ıe land in December, is again found there in January, and moves out ocean-ards in February. Its position in October is an exceptional one. It is ırther south and very much farther west than in any previous year. When ıe Scandinavian system is examined, it shows the same peculiarities in the last wo months of the year, being a good deal south and very much west of its ormal position. In the early months of the year it was far east, and the osition of its core is not discernible.

There were 27 occasions on which the core of one of the systems was over ıe British Isles ; 13 were due to the Atlantic system, 3 to this system when ıerged with the Scandinavian, and 1 when merged with the Greenland system, hile 5 were due to the Scandinavian alone, and 5 to the Greenland system lone.

1889 (Fig. 9).—We found both the Atlantic and Scandinavian systems far west during the latter end of 1888, and we find them west of their normal positions in the beginning of 1889. There is nothing exceptional in their positions during the rest of the year.

There were 15 instances of a core being over our islands; of which 8 were due to the Atlantic system, 6 to the Scandinavian, and 1 to the two systems when merged.

1890 (Fig. 10).—The core of the Atlantic system is very far west in February and, as was the case in 1887, that of the Scandinavian is also far west. Each is on the same parallel as in that year. The movements during the year call for no remark. There is the same drifting of the Scandinavian core in October, November, and December from the north of Scandinavia southwards and eastwards as usually takes place in these months, while the core remains far west, as it did in 1888, during December. The core of the Atlantic system also is well out over the ocean in November and December, and does not return to land.

There were 20 instances of a core being over the British Isles, of which 14 were due to the Atlantic system, 1 to the Scandinavian, 2 to these two combined, and 3 to the Greenland system.

1891[1] (Fig. 11).—As in previous years we find that the Atlantic and Scandinavian systems being far west during the later months of the preceding year, their cores are found far west in the early months of the following one. For the exceptional positions of their cores in February, the year 1891 resembles 1887 and 1890, and in all three years they are to be found on the same parallel of 30° and 50° respectively.

On 16 occasions there was a core over our islands. Of these, 8 were due to the Atlantic system extending over our area, 5 to the Scandinavian, and 1 to the Greenland, while 1 was due to the Atlantic and Scandinavian merging, and 1 to the Atlantic and Greenland systems merging.

Cores over the British Isles, 1881-91.

If we analyse the whole of the cases from 1881 to 1891 (September, October, and November 1883, and December 1891 being missing), in which the core of an anticyclonic system was over these islands, and the number of days it remained in that position, we obtain the results in Table II.

Out of a total of 212 cases, 130 were due to the Atlantic system extending over the British Isles, 41 to the Scandinavian, and 17 to the Greenland; 22 to the Atlantic and Scandinavian systems extending and merging and a core moving over us, and 2 to the same thing occurring in the case of the Atlantic and Greenland systems. Both in this analysis and in Figs. 2 to 11 I have distinguished between the Scandinavian and Greenland systems if it has been possible to do so, and whenever a core originating from the Greenland high pressure area during the summer months has moved over Scandinavia and shown all the characteristics of the Scandinavian system, it has been classified with that and not with the Greenland system. It is evident that we owe the greatest number of our anticyclones to the Atlantic system. They occur in all months but more especially in January, June, and October, and are least frequent in April and November. When such anticyclones move away from our area, the direction is very much influenced by the season of the year. By far the largest number that I have

[1] The series of these Maps which have been consulted ends with November 1891.

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traced drift off in some direction between north-east through east to south and take the more southerly course in December, January, and February. Some few between April and July move west or south-west, and still fewer north or north-west. In some instances the arrival of the core over the British Isles will give rise to the formation of the Scandinavian system, which up to that time had not been visible on the charts. The Atlantic system will separate entirely from the Scandinavian, and the latter will move on with the usual characteristics of the season. In these cases no preliminary extension of the Scandinavian system in the direction of our islands takes place. The indications are in favour of the idea that the atmospheric conditions over our islands

TABLE II.

Month	Core belongs to									
	Atlantic System.		Scandinavian System.		Greenland System.		Atlantic and Scandinavian merged.		Atlantic and Greenland merged.	
	Cases.	Days.	Cases.	Days.	Cases.	Days.	Cases.	Days.	Cases.	Days.
January . . .	14	31	...	...	2	3	2	8	1	4
February . .	12	20	7	10	...	...	3	4	...	...
March . . .	7	18	5	9	3	6	1	5	...	...
April	7	14	1	2	3	10	...	...	...	...
May	11	25	7	11	1	1	2	3	...	...
June	19	38	5	16	3	6	1	4	1	3
July	11	26	1	2	...	...	1	1	...	...
August . . .	12	20	2	3	1	1	2	9	...	...
September . .	8	22	6	14	1	2	3	9	..	...
October . . .	13	30	3	8	2	9	2	5	...	...
November . .	5	16	3	5	1	1	2	2	...	...
December . .	11	27	1	1	...	...	3	5	...	...
Total . . .	130	...	41	...	17	...	22	...	2	...

foster the formation of an anticyclonic core, and the centre of the Atlantic system is displaced accordingly in our direction, but that the cores do not continue long in our neighbourhood, owing in the first instance to the ever-varying seasonal changes of temperature, and next to those brought about by the general atmospheric circulation. These two influences appear to me to be of supreme importance in determining the direction in which any anticyclonic system will move.

Connection between the Anticyclonic Systems.

Looking at Figs. 2 to 11 (Plate 5) as a whole, we see many instances of a displacement of the core of the Atlantic system in a westerly direction during February, and we notice that an extreme westerly position, such as occurs in 1887, 1890, and 1891, is reciprocated by the Scandinavian core which is also unusually far west. Many indications of the existence of a connection between the movements of these two systems can be traced in the figures. The position of the Atlantic core in August seems to vary very little indeed, being always about lat. 35° and long. 35°, as in Fig. 1. The westerly movement of the Scandinavian core in the early months of the year, and its return eastwards from September to

the end of the year can be seen in nearly all the figures. It is interesting to notice that there are certain localities affected by the core of this system in going and returning during successive years, though it may be traversing the region at very different times of the year.

In conclusion, the figures confirm in an unmistakable manner the interpretation which was put upon Fig. 1 in connection with the Atlantic and Siberian systems. Loomis looked upon the "Europasia high level area" as *one* area with two or more centres, of which he found that the eastern centre was in winter generally higher than the western. In Fig. 1 the Siberian or eastern centre was tracked to the Polar regions after it had left the land, and in Figs. 2 to 11 we have followed the Scandinavian or western centre in its movements to and from the same regions. They represent graphically the displacement of the centre in successive months, and prove conclusively that there is a regular progressive movement of the system in the directions that have been pointed out. That it has been tracked to such northern regions as those round Spitzbergen and Greenland will come as a surprise to many, but the evidence is overwhelming, and until it is disproved by fuller information than is now at our disposal, the conclusion must be allowed to have a great deal to support it. If further investigation should confirm the views that have been advanced in this paper, and should enable predictions to be made of the probable movements and positions of the centres of the anticyclonic systems, we shall have a valuable addition to our present method of forecasting by means of synoptic charts.

Appendix I.

Analysis of the Movements of the Anticyclonic systems which appear on the "Synchronous Weather Charts of the North Atlantic" for the period August 1, 1882, *to September* 3, 1883.

Up to the present very little has been published respecting the extremely valuable series of *Synchronous Weather Charts of the North Atlantic* and adjoining continents, published by the Meteorological Council. They embrace an area from long. 120° W. to 30° E., and from the Equator to the Polar regions; and within this the movements of the Atlantic, Scandinavian, American, and Greenland anticyclonic systems are depicted, by daily synchronous charts of the isobars and isotherms at Greenwich noon. As an appendix to the preceding paper, the following analysis of the movements will be of use to those to whom the charts are not accessible. It does not attempt to deal in any detail with the smaller movements of the systems, nor with those of secondary cores, but to give a general idea of the incessant shifting of the high pressure areas as their centres are displaced by seasonal and other influences from month to month.

1882. *August.*—In the early days of the month an area of high pressure is found lying across the British Isles from south-west to north-east, with a core to the south-west of our coast. By an extension to south-west and the appearance of a core there, the area can be identified as belonging to the Atlantic system. The original core moves north-east over our islands, and after remaining stationary for a time is separated by intervening depressions from the rest

of the system, and moves off north-east beyond the limits of the charts. It has drifted, we know by experience, to join another high area, and by the direction taken we infer this is far north and must be the Scandinavian system. The Atlantic core remains fairly central (lat. 40° N.), till on the 19th it begins to drift north-east, nearly reaching these islands by the 30th. The whole system then extends west across the Atlantic. The American system cannot be identified with any certainty. There are indications that it is far north-west, and from 17th to 23rd a core drifts east across the Canadian Lake district.

September.—The Atlantic core, which was driven back from the British Isles on the 1st and 2nd, returns and joins a system which appeared over Central Europe on the 1st, and which can be identified as the Scandinavian. After they merge a single core is over these islands from 6th to 8th, and then they are separated by a deep depression from the north-west which drives the Scandinavian system and its core north-east and the Atlantic core central over the ocean (45° N). The former is not seen again till the 18th, when it is far north-east over Russia. The Atlantic system, after extending into the Polar seas, is found from the 19th to 21st covering the whole area from Norway to Florida across the British Isles with its core now off Newfoundland. This core drifts steadily south-east from this position till it reaches the African coast (30° N.), on 29th. During this southerly movement the Scandinavian system also moves south on to our charts, and extending south-west joins the Atlantic system on October 1st. The American system begins to make itself very evident after the 12th. A core which has appeared north of the Lake district is then seen drifting south-east till it reaches the ocean on 14th, and then moving somewhat north-east it merges into the Atlantic system on the 14th. Similar cores follow on the 20th and 24th, while a third appears later moving south-east from the far north-west.

October.—The core of the Atlantic system moves steadily north-east and is over the British Isles from 4th to 6th. From the 7th onwards core after core drifts across from America to Africa, reaching as far south as 30° N., and there is a distinct tendency for such cores to pause off the coast and extend the high pressure north-east towards Central Europe before disappearing. The Scandinavian system appeared over the North Sea and Norway from 7th to 9th, formed as it were out of the Atlantic system when it was driven back from the British Isles, and it remained till the middle of the month in those regions. On extending south towards Central Europe it joins the Atlantic system there on the 20th, but returns immediately to the north-east. Across the Lake district of Canada successive cores are following one another throughout the month. They come from the far north-west, and having reached the lakes they take an easterly course on to the ocean and drift out to merge into the Atlantic system. In the latter part of the month they originate further south and come from almost due west. On the 25th a case occurs of a core drifting as far south as 30° N. and passing across Florida for the first time, after which it pursues a north-east course and finally merges into the Atlantic system over the ocean on the 30th. This east and south-east movement of cores is continued across the ocean to the Spanish coast and is a feature of the month.

November.—The core of the Atlantic system is seen travelling rapidly across from America to Spain, and is over the Iberian peninsula on the 4th. This remarkable movement ceases after this date, and for the rest of the month the core is never far from this locality, always tending landwards if driven out to sea and appearing to hug the land. The system extended north-east over the British Isles, and covered them for three or four days after the 12th, but was generally further south. On this occasion it gave rise to the Scandinavian system which had been seen over Russia early in the month, but from 6th to 13th had been invisible. It again becomes invisible on the 20th, being driven

north-east and separated from the Atlantic system by depressions. The cor the American high pressure is over the Lake district (50° N.) on 2nd, ha moved south from a new and more easterly region to the west of Greenla and drifts steadily east towards Newfoundland. Extending south-west for first time, its core moves on till it lies over Florida on the 10th, after whicl is seen to extend north-east to join with the Atlantic system and to form unbroken area of high pressure across the Atlantic to Norway. Simultaneou with this extension another core appears in the far west, moving south-e From the 13th to the end of the month this system remains fairly central acr the States, extending sometimes to cover the Gulf of Mexico, sometimes Flori and sometimes a little into the Atlantic, and cores moving in these directio but they are unusually persistent over the land and never move out to join Atlantic system as they did in October. We feel convinced that we are foll ing the movement of the true American system on its progress south as sho in Fig. 1.

December.—Throughout the month the core of the Atlantic system is i southerly position (30° N.), and central over the ocean, only moving to Sp and covering Central Europe with high pressure late in the month. It mo north after the 17th, and extends north-east to meet the Scandinavian syst south of the British Isles on the 20th, this system appearing then from t north for the first time and moving east. High pressure is found during t month over Greenland actively extending across to North America and givi rise to cores over Iceland and West Greenland. Over America the same mo ment of cores from the north to the Gulf of Mexico, and thence east to t Atlantic, takes place as in the latter part of November, and on the 5th, 10 and 13th they are seen to move out on to the ocean and merge into the Atlan system, but this does not occur later in the month. The Greenland hi pressure sometimes extends south to merge with these cores, of which 7 can traced. The last core came more from the west than the remainder.

In the movements that have been recorded so far, I would draw spec attention to the influence of locality in determining the course which pursued by the cores. Contrasts of temperature to be found over the La district of Canada, the course of the St. Lawrence, Newfoundland, No Scotia, and Florida, are evidently of great importance in controlling t systems over America, while the same control over systems on our side exercised by the British Isles, by the sea-girt Scandinavian region, and t the Iberian peninsula. When cores move off on to the ocean from t American continent, the core of the Atlantic system will invariably found near at hand, indicating a locality where atmospheric influences a at work to give rise to or control the movements of anticyclonic cores. October a number of cores move out over the ocean from America, and t Atlantic core is often seen there. In November the latter core is ne Spain, and no cores leave the American coast. In December they dri oceanwards in the early part of the month only, when the Atlantic core central, and cease to do so when it moves to Spain. The influence of locali will also suffice to explain the instances in which the Scandinavian syste seems to grow out of the Atlantic system when its core reaches the Britis Isles, though it has not been visible previously in this region. It is great interest to note the relative positions of the centres of maximum pressur and of maximum contrasts of temperature as indicated by the isotherms, a to follow the changes in the maximum isobar as a core approaches and reced from any locality, but these are questions outside our present inquiry.

1883. *January.*—The Atlantic system is south, with its core over Spa It moves north, and a core is over the British Isles on the 4th. Out of this hi area the Scandinavian system, which has been invisible hitherto, is formed

the 5th, and its core covers Norway and the British Isles till the 9th, when it is driven north-east. The Atlantic system recedes south-west after the 6th, and is found merged with the American system, far west, on 13th. Its core is then central (35° N.), and moving steadily east it reaches Spain on 17th, when the system as a whole extends north-east to join the Scandinavian, which has moved south-west. The two then cover all Central Europe. They are separated on 19th, and after extending over the British Isles, the core of the Scandinavian system moves west and north. The Atlantic system is not long in the west, its core returning over Spain, and an extension north-east to rejoin the Scandinavian again takes place. Simultaneously another core is seen travelling across the Atlantic from Nova Scotia for three days, keeping 60° away from the first. After the system becomes merged with the Scandinavian, the second core becomes the principal core of the system, and the two systems together move south. Again we find cores following one another in succession from the west or from North America till they reach the United States and, moving east, pass as far south as Florida and thence on to the Atlantic, when they merge into that system if it is far enough west. Occasionally such a core will come from the west, and will not go farther south than the latitude of Nova Scotia, and in all cases the influences of the Lake district upon the course they take is very noticeable. High pressure prevails over the land throughout the month.

February.—The continuous band of high pressure, made up of the Atlantic and Scandinavian systems, lies across Central Europe from south-west to north-east for the greater part of the month, and is only occasionally broken up. The Scandinavian core is sometimes seen far east over Russia, and also far north. That of the Atlantic system is constantly returning to the south and south-west of these islands, so as almost to cover them. In America the influence of the season has already begun to make itself felt, and the cores which travel across from the west, or from north-west, do not move much below the parallel 40° N. Only one core, quite at the end of the month, reaches as far south as the Gulf of Mexico. Most of them move towards Nova Scotia, and thence into the Atlantic, to merge with the Atlantic system, whose influence upon their direction is clearly seen.

March.—The Atlantic system which was over the British Isles at the end of last month now moves north-west for the first time so as to have its core frequently over Iceland, and the influence of the season in driving high pressure off the land begins to be very noticeable. The longer axis of the system, which has been west to east up to the 4th, is then turned north to south off the land, and an extension of the system northwards leads to the formation of the Scandinavian system over the ocean east of Greenland on the 14th. Until then the latter was not visible. The Atlantic system having given rise to the Scandinavian in the far north separates from it and takes up a central position over the Atlantic, from which it shortly afterwards returns north to merge again with the Scandinavian and remain far north over Iceland. By the end of the month both have entirely left the land, and a core of high pressure is seen moving west over Greenland to join that in the far north of America. The Scandinavian system remains in these regions but the Atlantic moves south, and its core is found off the west coast of Spain. Over North America during the first half of the month cores continue to drift till they reach the Lake district, after which they move towards Nova Scotia and pass on into the Atlantic to merge with the system there. But after the 15th there is an interruption to these movements which have been going on so long, and the American system can only be identified by cores which appear in the northernmost regions. It has merged with the Polar high pressure across Hudson's Bay and Greenland, and is recognisable by a core which travels south at the end of the month, returning north at once.

April.—The extension of the Atlantic system in a north-easterly direction during the last days of March brings the core over these islands on the 1st, while another core belonging to the same system is central over the ocean. Both drift north-east, so that the latter core reaches the British Isles on the 5th. It is over them till the 10th, when the westerly movement, away from the land, which was seen last month is again repeated, and the core drifts to a central position (45° N.). The Scandinavian system shares in this, and its general movement is south-west from the far north-east regions. The Atlantic core also moves south (30° N.), and on the 20th the system makes a sudden extension north-east to meet the Scandinavian, whose core is over the sea north-west of Norway, and to cover the British Isles with high pressure. It is driven back by depressions, but again extends north to meet the Scandinavian system which is now over Iceland, and it forms a core to the north-west of our islands. In the last half of the month the Scandinavian system is far north and gives indications of continuing its westerly movement as far as Greenland. The core of the American system which was seen on the north on March 30 disappears, and only two cores are found, over Hudson's Bay and the Lake district, during the month. Both move south-east to merge into the Atlantic system. It is noticeable that some cores of small intensity move from the west across Florida into the Atlantic, which appear to come from a very southerly locality, and possibly belong to the Pacific system.

May.—The tendency for the Atlantic system to extend north is very pronounced. Its core is constantly found as far north as 45° N., and the Greenland system sends a ridge south to join it occasionally. The Scandinavian system is hardly distinguishable. The American system is far north, and on the 5th is seen to extend as far south as Nova Scotia to join a high pressure system there which has come from the west. It can be followed east into the Polar high pressure area about Greenland. On three occasions cores drift across North America into the Atlantic which appear first in the far north-west.

June.—The Atlantic system moves west from a central position till it merges with a core off Nova Scotia which has moved slowly across the Lake district from the north-west. Together they cover all North America and the North Atlantic. On the 8th the Atlantic core is driven south from its peculiarly northern position, and drifting east the core comes over these islands on 11th and remains till 14th. The system generally extends north. The Scandinavian core had previously moved from Greenland over the British Isles, and on the approach of the Atlantic system it returned north. Leaving these islands the core of the latter drifts west along the parallel 50° N. till the 17th and then south. The Scandinavian system shares in this southerly movement and becomes visible again. It is noticeable that three times this month the Atlantic core moves to the American side and merges with cores which have travelled across the Canadian Lake district; and that southerly movements of this system are accompanied by simultaneous southerly movements of the Greenland high area. The American system cannot be identified. Occasional cores appear from the west and travel south-east over the Lake district, but they are of a secondary character.

July.—The Atlantic system which extended north to the British Isles at the end of June has again moved south and central (30° N.), and the core of the Greenland system has come south also. Extending to meet one another the Atlantic core drifts east to the Bay of Biscay, and oscillates to the centre (45° N.) and back again before moving north-east to cover the British Isles on the 27th. The Greenland system can be traced throughout the greater part of the month moving south to join the Atlantic system and to cover Iceland with high pressure. On the 30th there is a core to the west of Greenland which may indicate the position of the American system, but otherwise it is not

visible. Cores continue to travel from the north and north-west over the Lake district, but do not move out on to the ocean, nor persist in any locality.

August.—The Atlantic system, whose core is central over the ocean, extends east and moves north so as to cover these islands from 2nd to 5th. The core then moves 5° south (35° N.), and the system extends into Central Europe. On the 8th it stretches across the Atlantic to Nova Scotia, where it merges on 11th with a core which has drifted from the north; after merging it moves steadily to Spain, which it reaches on 16th. It then extends north-east, and on the 19th the core is over the British Isles, and gives rise to the Scandinavian system, from which it separates to take up a central position. The Scandinavian core persists over the Baltic till 22nd and then disappears. A core from the Atlantic system again shifts over these islands on 23rd and finally withdraws central (35° N.). The position of the American system cannot be determined. It appears to be far north, and such cores as drift south or south-east over Nova Scotia to merge with the Atlantic system come from north-west of Hudson's Bay.

A written description of the movements depicted on the charts cannot fail to be somewhat unsatisfactory, but it will be quite evident that not only do the systems themselves extend in various directions, and show a progressive movement according to the season of the year, but that their centres are being incessantly displaced within the area of high pressure. A striking feature in the case of the Atlantic core is the influence the air isotherms of 65° to 75° have upon its position and movement. This is seen in nearly all the charts, and it will be remembered that the mean surface temperature of the North Atlantic is about 72° over the regions traversed by this system.

DISCUSSION.

The President (Mr. F. C. Bayard) said that Major Rawson deserved great praise for his paper, the analysis of such a number of charts and matter involving a large amount of time and labour. He should like a definition of the word "core" as used in application to an atmospheric system, and also used many times in the paper.

Mr. R. H. Curtis said that Major Rawson's paper deserved very careful study, because it advanced some views as to the movements of anticyclonic systems which were not in strict accordance with hitherto received opinion, but which were certainly not to be lightly passed over on that account, since our present knowledge of the whole subject was most vague and unsatisfactory. He should therefore feel great diffidence in offering any criticism upon Major Rawson's conclusions until he had had an opportunity of giving the entire paper the careful consideration which it certainly deserved. But there was another point upon which he might be permitted to offer a remark, since it was a point upon which he had had some experience, and that was as to the method which had been pursued in the present investigation. Major Rawson had apparently a strong faith in the value of synchronous weather charts, and had made as full a use as possible of all data of that kind which he could secure. He (the speaker) was confident that in this Major Rawson was quite right, and that only in this way was it possible, at present at any rate, to make any progress in the study of the movements of weather systems, and of the laws by which those movements were governed. There were difficulties in the way of their use, and one of the chief of these lay in the fact that such charts covered, as a rule, but a very small area, such as the western portion of Europe, while for the purpose

of this study it was necessary to have a synoptic view of a large area of the globe, which should embrace the ocean as well as the land; but Major Rawson appeared to have pieced together, as far as possible, the various charts in existence, and to have made a full use of the synchronous weather charts of the North Atlantic, published by the Meteorological Office, which were no doubt the best charts for the purpose in existence. In following this line of investigation there was little doubt that he would get better and more reliable results than any mean values would yield him, based as these often were upon observations few in number and poor in quality, when they were for out-of-the-way places. The labour which had been expended upon the investigation deserved every recognition.

Mr. C. HARDING endorsed what had been said as to the merit of the paper, and said it had long been recognised that if forecasting was to make any advance it would be through the study of the movements of anticyclones rather than cyclones, as the one was the main controlling power of the other. He was disposed to believe that both Major Rawson and Mr. Curtis, in their reference to Prof. Loomis's investigations, referred to some earlier works of his, as in his later publications the limit Loomis gave for anticyclones was certainly as low as 30·2 ins. He (Mr. Harding) took exception to Major Rawson's method of taking the extreme reading of an anticyclone, and to assume its movements as the general movement of the system. A depression skirting to the northward of an anticyclone would eat its way into it, and small secondaries would also largely affect the system in this way, so that often in the instances where Major Rawson said the movement has been greatest, in reality there has been no movement at all. Broadly spreaking, the movement of anticyclones had been fully recognised for many years, although the question of movement was dealt with in a different manner from that now proposed by Major Rawson. The centre of an anticyclone was not nearly so well defined as that of a cyclone. He did not quite like the author's reasoning with reference to the Northern and Southern Hemispheres, and thought Major Rawson had dealt too much with mean charts. The isobars round the North Pole were lower in summer than in winter, according to Dr. Buchan. In conclusion, he would certainly say that he was entirely opposed to fixing on a certain high reading and to follow it up and call it the "core." A clearing of the sky might raise the barometer a tenth of an inch, and to label that the "core" and trace it as such would be an erroneous proceeding.

Mr. G. J. SYMONS said that he was more than ever thankful that he had never been responsible for weather-forecasting, but thought with Mr. Curtis that the tracking of the course of anticyclones was the key to that branch of meteorological work. With regard to the exception taken by Mr. Harding to Major Rawson's method, he (Mr. Symons) did not see any other available course than that adopted for following the movement of the systems by the author of the paper, viz. the tracking of the cores day by day. He had always believed temperature to be dependent upon atmospheric movements, but apparently there was now doubt as to which was cause and which was effect. It had occurred to him on looking at the maps to ask whether there was any relation between the movement of "cores" and the variation of solar spots.

Major H. E. RAWSON, in reply, said he knew that he had brought revolutionary ideas before the Society, and was therefore prepared with confirmatory evidence and data to bear himself out. He had studied the Daily Weather Charts for all countries where issued, and before finishing them a definite conclusion had formed itself in his own mind. He then turned to the monthly charts, and finally wound up with Dr. Buchan's charts, which last, he found, contained an entire solution of the whole matter, and thoroughly bore out the conclusions formed from the examination of the others. The movement

northward was traceable in Buchan's charts, and he had not a doubt that they were right in assigning the high pressure to the regions there given. He could not adequately express his admiration for these charts. He cordially agreed with Mr. Harding's objection to the method of procedure when the "core" vibrates, but when the whole system moves bodily across such a vast area as the Atlantic he thought it quite a fair and trustworthy method. From the nature of the case, the "core" could not appear apart from the main system; and, on the whole, it followed the movement of the permanent high pressure system, and was indicative of it. He had especially distinguished the movements of subsidiary systems from those of the main. In reply to Mr. Harding, the quotations made from Loomis were from the latest edition, 1885. As to whether anticyclones determined low temperature, or whether the opposite holds good, when we knew the true relation of one to the other, a great advance would be made. In an anticyclonic system the coldest weather was not always experienced in the absolute centre of maximum pressure. For instance, in the case of the Siberian anticyclone, the district where the most intense cold prevails is 420 miles distant. Loomis found many cases in which the two centres were 400 miles apart. In answer to Mr. Symons's remarks, he (Major Rawson) could not help noticing that the resemblance to sun-spots to an observer who was not on our planet and was able to see both was most marked. We were now expecting results from Australia, dealing with anticyclonic movements in the southern hemisphere, which were likely to be of extreme value, and he hoped would confirm his own results.

Capt. H. TOYNBEE, in a note to the Secretary, wrote:—"I have read this paper with much interest, though I am sorry to say I have not been able to give it the attention it deserves, and have only glanced through the diagrams. I hope the author will continue his research as material grows. When reading Nansen's book I felt convinced that his ship was under the influence of systems of high and low pressure depending on the seasons, and that his observations would be most valuable for such work as Major Rawson's. Nansen's ship moved so slowly that she might be considered as a fixed observatory for each month.

"The author makes it clear that the changes in the position of the areas of high pressure are due to changes of temperature, but I do not remember that he alludes to the question as to how those changes are brought about. As an object-lesson, I may say that during my numerous voyages I well remember how on the southern verge of the North-east Trades in the Atlantic the upper clouds frequently moved from a southerly or south-westerly direction, and the current of air which carried them was called the Counter-Trade. This showed how, in the Equatorial Doldrums, the air brought into them by the Trade rose and passed away to the northward, I suppose to supply with the necessary air the anticyclone from which the North-east Trades flow; the light air having cooled during its passage north and eventually come to a zone where its gravity brought it down to the surface of the earth, forming the calms of Cancer, where the barometer remains high and steady, and the sailing-ship navigator longs for a fall in his barometer as a sign that he has got to the edge of that great plateau of high barometer, and will therefore get a breeze.

"These facts seem to indicate that the more or less permanent areas of high barometer, out of which various winds flow, are fed by upper currents of air which have risen over areas of low pressure. Land and sea breezes illustrate the same fact. It would be deeply interesting if numerous observations of the motion of upper clouds could be got for the different seasons and compared with the changes of position which take place in anticyclones. I suppose, however, parts of those upper currents are void of visible clouds, which idea is supported by the fact that I only remember seeing the upper clouds moving to the north-

ward, whilst the lower wind was North-east at the southern verge of the North-east Trades.

"I am such an antiquated meteorologist that it is quite probable all I have said is out of date, and that a more correct theory has been worked out."

Mr. H. HARRIES wrote :—"One cannot but admire the author's courage and patience in the preparation of such a lengthy paper, but now that it is before the Society for discussion the question naturally arises, 'Does the investigation lead us to any new train of thought, or does it tend to advance meteorological knowledge by a single step?' It is to be feared that those who have practical acquaintance with the great difficulties by which our weather problems are hedged round will find in this paper nothing that can be of assistance to them. The mean monthly distribution of barometric pressure over the globe is pretty well known to most of us ; but it is quite a mistake to suppose that the movements of either cyclones or anticyclones can be deduced from their monthly change of situation, which, as is evident from Figs. 1-11, is, in the case of anticyclones, usually infinitely small, and consequently meaningless, in so far as it helps us to explain what has taken place. The progressive movement of weather areas can only be traced by a laborious examination of the behaviour of the systems from day to day, and several times a day if possible ; and, as we are all versed in the fact that high and low pressure areas follow the most erratic courses, our endeavours should be not to waste time on monthly or annual means, interesting though these may be in themselves, but to ascertain what are the forces in operation to determine the direction and velocity of movement day by day. Cyclones and anticyclones act upon each other, and for practical purposes it is useless to treat of one without taking any account of the behaviour of the other. What we want in this connection is not that the author should go back to the antiquated work of laying down a complicated network of tracks, but that he, or any one else taking up the work, should improve on Dr. Köppen's method in his *Vierteljahres Wetter Rundschau*, a series of reviews of the conditions from day to day over America, the North Atlantic, and Europe for several years, published, with numerous charts, in many numbers of the *Annalen der Hydrographie und maritimen Meteorologie*. Anything falling short of Köppen's plan ought to be looked upon as unworthy of our consideration. The paper now submitted is far too long to be criticised in detail, but it may be well to call attention to one or two of its inconsistencies. In the second paragraph of *Previous Investigations* Mr. Scott's conclusion as to the replenishing of the Atlantic anticyclone from the westward is declared to be a wrong one, as 'it will be seen hereafter that is not the case' ; but when we come to *Facts recorded by previous Investigators*, this same work by Mr. Scott is a valuable testimony to the truth of the author's views. Precisely the same kind of contradiction appears in connection with the discussions by Loomis—his results were indefinite, and he failed to find any law governing the movements of anticyclones, and yet 'Fig. 1 and Table I. are in complete agreement with Loomis's facts, and offer a satisfactory explanation of the results which he obtained.' Adopting certain ideas as to the movements of Southern Hemisphere anticyclones, about which we know next to nothing, for there has been no attempt to discuss them properly, the author applies them to our northern systems, about which we have abundance of direct information in English, American, German, and other synchronous charts based upon large numbers of observations."

RESULTS OF OBSERVATIONS ON HAZE AND TRANSPARENCY IN 1897.

By the Hon. F. A. ROLLO RUSSELL, M.A., F.R.Met.Soc.

[Read April 20, 1898.]

The observations taken during 1897 mainly represent the daily mean visibility during the hours of late morning and early afternoon, that is, between 10 a.m. and 4 p.m. Many cases of high visibility were noted which lasted only for a portion of the day; others, especially with a steady breeze, lasted throughout the hours of daylight.

It was not convenient for me to observe the mileage of view hourly, as in 1895, and accordingly the results obtained are less complete. Yet the observations were taken about the same hours on each day, and are comparable. The first day of 1897 on which visibility was noted was January 20. No observations were taken on March 22, 23, 24, April 3, 4, 8, 9, 10, 11, 12, May 20, September 28, November 19, 20.

The place of observation was Haslemere, except from March 30 to April 13 (Richmond Hill), and from August 14 to October 5 (Highcliff, on the coast of Hampshire).

The following Table gives the order of transparency for the named wind-directions in the four quarters of the year, and for the whole year, compared with 1895.

TABLE I.—Visibility in Miles.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Variable and calm.
1st Quarter	5	10·5	16	(17)	17·2	18·1	24·9	15	9·5
2nd ,, ...	21·6	13·6	17	23·1	26	19·7	23·9	31·2	14·5
3rd ,, ...	17·7	10·4	17·4	23·5	25·8	29·6	29·7	30·5	18·2
4th ,, ...	18·6	7·8	10·7	9·7	16·1	16·7	17·7	10·3	13·5
Year 1897	15·7	10·6	15·3	18·3	21·3	21	24	21·7	13·9
Mean of 11 a.m. and 2 p.m., 1895.	13·4	10·1	13·9	15·7	24·7	25·4	29·7	23·8	16·4
Mean of the two years . . .	14·5	10·3	14·6	17	23	23·2	26·8	22·7	15·1

Order of winds in relation to clearness, middle part of day, 1897 :—
W, NW, S, SW, SE, N, E, Calm, NE.

Order of winds in relation to clearness, middle part of day, 1895 :—
W, SW, S, NW, Calm, SE, E, N, NE.

Order of winds in relation to clearness, middle part of day, both years :—
W, SW, S, NW, SE, Calm, E, N, NE.

The general order in 1897 was similar to that of 1895, as may be seen by tracing out the curves of the two years. The South-east wind verified the expectation expressed in the previous paper, that its place in the list would be raised with further observations.

The following Table may be compared with Table V. in the paper published in the *Quarterly Journal*, vol. xxiii. p. 145, giving the results for 1895. It shows the distribution of instances of high visibility in 1897 in a westerly and easterly quarter, and the relation of visibility to weather.

TABLE II.—Results of Visibility above 22 Miles.

Visibility.	Weather.			Following 24 Hours.		Wind between	
	Fine.	Some rain.	Wind, fresh or strong.	Fair.	Some rain.	SW and NW.	NE and SE.
22 to 50 miles (85 cases) .	49	35	34	54	31	58	12
50 miles and more (20 cases)	16	4	2	12	8	17	1
Total over 22 miles (105 cases)	65	39	36	66	39	75	13

Among W winds (all cases; SW to NW inclusive) the percentage of Westerly winds with views over 22 miles during at least a part of the day was . 49·1

Among E winds (NE to SE inclusive) the percentage was . . . 20·7

„ N „ (22 cases) the percentage was . . . . . 22·7

„ NE „ (32 cases) „ „ . . . . . 12·5

„ E „ (41 cases) „ „ . . . . . 9·8

„ SE „ (10 cases) „ „ 40

„ S „ (24 cases) „ „ 25

„ SW „ (55 cases) „ „ . . . . . 45·5

„ W „ (66 cases) „ „ . . . . . 45·5

„ NW „ (23 cases) „ „ . . . . . 56·5

The order is different from that of 1895, but the smallest proportion of cases of high visibility remained between East and North, and the largest between South-west and North-west. The number of cases of South-east wind were too few to allow much value to the position of this wind in the order of special clearness; it generally affords a smaller proportion of days of high visibility than the South wind.

The order of winds for cases of high visibility was as follows in 1895 and 1897:

1895.—W, SW, S, NW, Calm, SE, E and N, NE.
1897.—NW, W and SW, SE, S, N, NE, E.
Both years.—W, SW, NW, S, SE, N, E, NE.

The percentage of days of transparency in the whole number of days of each wind in the two years was as follows:

N	NE	E	SE	S	SW	W	NW
18·8	11·8	12·4	32·5	36·5	49·3	49·9	44·5

DISCUSSION.

The President (Mr. F. C. Bayard), in thanking Mr. Russell for the paper, said it formed a valuable addition to that read before the Society last year.

Mr. H. Southall inquired whether there was much variability in the degree of transparency for different parts of the country. A friend of his had built a house in Lancashire with a prospect of some 20 or 30 miles, but it was not many days that the glories of the view were visible, the atmosphere in that county being almost one constant haze. It was a great advantage to have these supplementary observations, carried on as they were by the same observer, and on precisely parallel lines to the former ones. Mr. Russell's results agreed remarkably well with his own, both as to time of day and point of compass.

Mr. R. H. CURTIS remarked that it was important to know in what direction, relative to the direction of the wind, the range of vision had been tested; whether any rule had been observed for doing so to windward or leeward, or always in the same direction irrespective of the wind. It was also desirable to give the bearing and distance from the places of observation of any towns or places where much smoke might be generated, because there could be no doubt that masses of smoke sometimes drifted in gentle air-currents for great distances, without being broken up and dispersed in the same way as usually happened when the winds were strong. It seemed quite possible that these masses of matter would cause a haziness of the atmosphere to windward, and produce a decided effect upon its transparency when tested by the range of vision, in that direction especially, although they might have become so attenuated as not to be perceptible in any other way. Such an effect was common enough at considerable distances from manufacturing centres, and it would be very difficult to say at how great a distance it would continue to make itself felt. He noticed that in the paper some of the observations were said to have been made at Richmond, which place, being in the close neighbourhood of London, would certainly be affected by the smoke of London when the wind was Easterly, and this fact had been well shown by the comparisons which had been made of the amounts of sunshine recorded at the Kew and Greenwich Observatories with different winds. But as further illustrating the effect of the direction of the wind upon the atmosphere in the neighbourhood of London, he might say that a few days since, when a very light Westerly air prevailed, the amount of bright sunshine recorded at the Kew Observatory was 90 per cent of the possible amount for that day; in the neighbourhood of Putney Bridge, a few miles to the eastward, it was only 66 per cent; still farther east, at Westminster, it was reduced to 30 per cent; and at Bunhill Row, in the City, it was diminished to 5 per cent; while at Plumstead Common, with London, as a whole, to windward of the station, no sunshine at all was recorded from sunrise to sunset; so that, while at Richmond, with London to the leeward, the day was perfect, at Plumstead it was gloomy and dull. There could be no doubt whatever that two observers recording the transparency of the air at those two stations would have attributed a totally different character to the Westerly wind, for which in reality the smoke of London was alone responsible.

Mr. G. J. SYMONS said that roughly one could see that the winds with a low percentage of visibility were those blowing from the direction of London. Westerly winds were much higher. In his opinion the atmosphere was getting dirtier year by year. A cloud of smoke from Lancashire had been driven across the Irish Channel and nearly to the South of Ireland, when an adverse wind drove it part way back and it was deposited as "Black Rain."

Mr. F. A. R. RUSSELL said, in reply, that he could not state anything positively as to the amount of haze in the north compared with the south of England, but was inclined, from observations he had made in Scotland, to the belief that haze was more prevalent in the north. Although he strongly realised, with Mr. Curtis and Mr. Symons, the widespread effect of smoke from towns, he could by no means consider smoke as a principal cause in the results given, which, with those described in his previous paper, show a gradation of haziness from a maximum about east-north-east to a minimum about west. Observations made at 8 a.m. could hardly be affected by smoke. Neither smoke, nor the distribution of land and sea, nor any local condition in this country, could account for the differences observed, which were due, as he endeavoured to show in a previous paper, to the mixture of currents of air of different temperatures. The East wind in a great part of Europe was often accompanied by haze, and he had been assured by a captain accustomed to navigate the Mediterranean that in the western part of that sea the haze brought

by this wind was often dense enough to hide objects at two miles distance. On the Riviera in Italy the East wind frequently brings both haze and rain. On the east coast of Scotland an East wind, even though local and temporary, produces haze. Mr. Russell said, in conclusion, that he had intended to illustrate his paper by a wind-rose diagram, such as Mr. Symons kindly suggested, but found that it would be desirable to have further data before fixing the results in this form.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 16, 1898.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

ROBERT GRAY, Botolph House, Winslow;
WILLIAM R. GRIFFITH, Rydal Mount, Bangor;
JAMES EDWARD PRICHARD, B.A., M.B., 243 Cheltenham Road, Bristol;
FREDERICK P. PULLAR, F.R.G.S., The Lea, Bridge of Allan, N.B.; and
WILLIAM HAROLD TINGEY, B.A., Rede Court, Rochester,
were balloted for and duly elected Fellows of the Society.

Mr. ARTHUR W. CLAYDEN, M.A., F.R.Met.Soc., gave a lecture on "PHOTOGRAPHING METEOROLOGICAL PHENOMENA," which was illustrated by lantern slides (p. 169).

On the motion of Mr. R. H. SCOTT, seconded by Dr. C. T. WILLIAMS, a vote of thanks was passed to Mr. Clayden for his lecture.

April 20, 1898.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

JAMES TERTIUS COLLINS, J.P., Churchfield, Edgbaston, Birmingham;
FRANCIS ARTHUR DARTON, Clare Lodge, Woodford;
MARTEN LLEWELLYN EVANS, 2 Naunton Park Villas, Cheltenham; and
THOMAS GORDON HEIGHINGTON, 33 Hill Street, Knightsbridge, S.W.,
were balloted for and duly elected Fellows of the Society.

The following communications were read:—

"ANTICYCLONIC SYSTEMS AND THEIR MOVEMENTS." By Major HERBERT E. RAWSON, R.E., F.R.Met.Soc. (p. 180).

"RESULTS OF OBSERVATIONS ON HAZE AND TRANSPARENCY IN 1897." By the Hon. F. A. ROLLO RUSSELL, M.A., F.R.Met.Soc. (p. 207).

CORRESPONDENCE AND NOTES.

Honour for Mr. R. H. Scott, F.R.S.—We have much pleasure in announcing that at the Summer Commencements of Dublin University on June 30,

the honorary degree of D.Sc. was conferred on our esteemed Foreign Secretary, Mr. Robert H. Scott, F.R.S., the Secretary of the Meteorological Office. We offer our congratulations to Dr. R. H. Scott, and trust that he may long be spared to enjoy this honour.

Note on Maximum Thermometers.—I have read with interest Dr. Chree's note on Maximum Thermometers in the January number of the *Quarterly Journal* (p. 51), referring to mine published in the preceding issue. Dr. Chree does not challenge the accuracy of my note generally (*i.e.* he does not dispute that the reading of a maximum thermometer of the Negretti and Zambra pattern, taken when the temperature of the surrounding air has fallen considerably below that of the maximum for the day, is too low), but points out that the figures given in my table are in excess in some instances by 16 per cent. In this he is undoubtedly correct, as I neglected the expansion of glass in computing my table, considering at the time that a coefficient of expansion, correct to four places of decimals, was sufficient for my purpose, and observing that the expansion of glass would affect the fifth place only. It would of course have been better to have carried the computation at least one place further, *i.e.* to have used as a coefficient 0·00009 instead of 0·0001. The difference between a table computed on Dr. Chree's figures and mine amounts in one place to 0°·15, in eight to 0°·1, and in the other cases to 0°·05, or agreeing exactly with my figures. My table was originally computed several years ago for my own use, and was of course intended to apply only to my own thermometer. Thanks to Dr. Chree's reference, I have obtained Leyst's paper, and note that he deals also with the correction of wet bulb readings due to the temperature of the stem being higher than that of the bulb. In no case would this be large at my station, my greatest recorded difference in readings between dry and wet bulbs being 24°·9 when the dry bulb read 98°·8. As the mercury would sink into the bulb at +10° Fahr., this would give a correction of 0°·18, using Dr. Thorp's empirical coefficient of expansion (0·0000795) which applies to such cases.—THOMAS WALKER FOWLER, M.C.E., F.R.G.S., the University of Melbourne, Victoria, *May* 18, 1898.

Rainfall of 31·72 ins. in Twenty-four Hours at Nedunkeni, Ceylon.—Mr. H. Parker, F.R.Met.Soc., Irrigation Assistant, has favoured us with a copy of his Report to the Director of Public Works, Ceylon, on the remarkably heavy rainfall of 31·72 ins. in twenty-four hours at Nedunkeni. This is so interesting that we reproduce it *in extenso*:—

"My recent visit to the Northern Province has given me an opportunity of making some inquiries regarding the abnormal rainfall of December 1897 at Nedunkeni, and I have the honour to submit the following report on it:—

"Nedunkeni, 11 miles down the southern road to Mullaittivu, and 122 feet above sea-level, is a small village at which there is a dispensary, with quarters for the Medical Officer stationed there, and two small bungalows for the use of Revenue and Public Works officials when travelling. It is a little to the east of the dividing ridge of North-Central Ceylon, and though itself in the catchment area of the eastern Per Aru, which flows through Tannir Murippu tank, it is only a little to the south-west of the point where three separate drainages meet. Forest, containing a thick growth of high trees, extends over the neighbourhood, and more especially for many miles from the south to the east.

"The staff at the dispensary consists of a Medical Officer, a Dispenser, and an hospital orderly. For about three years a rain-gauge has been established in the grounds of the dispensary, and its records are regularly transmitted to the Public Works Office, and are published among the rainfall returns.

"Although the mean *annual* rainfall at Nedunkeni is probably little more than 50 ins., the fall for December 1897 was 67·07 ins., and of this amount

31·72 ins. were measured at 9.30 a.m. on December 16, as the rainfall of the preceding twenty-four hours. Unprecedented floods were caused by it throughout this part of the district, and 162 tanks were breached by the water which poured over their embankments, while water passed from 18 ins. to 2 ft. 6 ins. deep over the bridges on the northern road to Mullaittivu.

"The only rainfalls above 15 ins. previously recorded in Ceylon, according to the last published Annual Returns (for 1896), have been 18·75 ins. on December 14-15, 1896, at St. Martin's estate, Rangalla, Central Province, 3600 ft. above the sea-level, with an annual mean fall of 173·56 ins., as entered in the Return of the Surveyor-General; and the following amounts entered in the Public Works Department Return:—

Station.	Height above Sea-level. Ft.	Maximum Rainfall. Ins.	Date.
Devilane, E.P. . .	166	19·50	Sept. 8-9, 1884
Padupola, C.P. . .	1636	18·80	Sept. 8-9, 1872
Ambare, E.P. . .	65	18·50	Jan. 15-16, 1876
Avissawella, Sab. .	105	17·90	Oct. 15-16, 1893
Tenepitiya, N.W.P. .	9	17·60	Oct. 19-20, 1891
Ambanpitiya, Sab. .	729	16·65	Aug. 6-7, 1886

The accuracy of these last records of falls has not been investigated, and it is quite uncertain to what extent they can be accepted. So far as Ambare is concerned, the method of measuring the rainfall that was in practice when I visited that tank last year was so rough as to render any high measurements obtained there valueless.

"The gauge at Nedunkeni is fixed on a plot of short thick grass inside the dispensary enclosure. Its top, 5 ins. in diameter, is 2 ft. above the ground, and the mouth of the funnel has a vertical rim 2 ins. high. The bottle will hold a rainfall of 4½ ins., and is completely enclosed in a water-tight receptacle, in which any surplus rain collects when the bottle overflows. The rain is measured in an ordinary graduated half-inch measuring glass.

"The rainfall of December 15 began at Nedunkeni at about 6 o'clock in the morning, and continued without intermission until some time on the following day. That which fell before 9.30 a.m. on the 15th was entered as usual to the previous day's account. At noon, at 3 p.m., and at 6.30 p.m., the bottle in which the rain was collected was emptied into an ordinary wash-hand basin by the Medical Officer or the Dispenser, having overflowed into the receptacle at 3 p.m. (this water also being emptied), and being full at the other times. The orderly states that during the night, acting on instructions given in the evening by the Medical Officer, he emptied it twice. On the first occasion it had overflowed, and all the water was poured into the basin, which was then nearly full. On the second occasion, the bottle was full, and he poured the water into the ewer belonging to the wash-hand set, after first examining the latter to see that it was empty. At about 7 or 7.30 a.m. on the 16th, the Dispenser emptied the bottle into the ewer, and again at 9.30 a.m., when it was about seven-eighths full. The whole of the water was then measured by the Dispenser, in the presence of the Medical Officer and the orderly. The Medical Officer is now stationed at Mankulam; the account that he gave me there agreed with that of the Dispenser and the orderly.

"By a fortunate accident, this rainfall has occurred at a station where there is the check of a quite unusual number of observers. Practically the only doubt that can be felt with regard to the all-important check of the number of times the bottle was emptied is with reference to the statement of the hospital orderly that he went out twice in the night to examine and bring it to the house. With respect to this it may be noted that the intensity of the rain from 9.30 a.m. to 6.30 p.m. on the 15th was almost exactly 1½ in. per hour. The

Medical Officer informed me that heavy rain continued up to past 8 p.m., after which it became lighter. According to the hospital orderly's evidence, we have for the next thirteen hours after 6.30 p.m. an intensity of a trifle more than 1 in. per hour, and this is only about two-thirds of the intensity of the succeeding two hours up to 9.30 a.m. on the 16th. There is therefore no evidence that the statement of the orderly is untrustworthy; on the contrary, this closely agrees with the actual measurement made on the 16th by the Dispenser and the Medical Officer. If we accept his statement, a total of $6\frac{7}{8}$ bottles has been accounted for; this would be about 31 ins., or 0·72 in. less than the measurement, this balance being the water that had overflowed from the bottle.

"Thus, so far as the recorded measurements go, they may be accepted as correct. Whether they represent the actual rainfall is another matter. There are other possible causes of error to be considered:—

"(*a*) Splashing, caused by raindrops falling on ground covered by a film of water. It is possible that during the greatest intensity of the fall there may have been some slight splashing into the funnel of the gauge; but the protection afforded by the grass, and the height of the mouth of the gauge above the ground level, could not but prevent this from being of importance.

"(*b*) The presence of tall trees on the windward side of the gauge is a much more serious cause of error. While part of the heaviest rain was falling, a wind, described as 'moderate' here in this forest, but 'strong' at Kanukeni tank, 11 miles away to the north-east, was blowing from the West, and veering round to the South-west, in which directions two leafy trees, 93 feet high, are so near as certainly to intercept a considerable quantity of rain if it fell at an inclination even much steeper than 45°. It is impossible to even guess the loss from this cause; but it may safely be asserted that there must have been some, and that possibly it was considerable.

"(*c*) The loss of rainfall while the bottle and receptacle were removed in order to be emptied. This cannot be estimated; its total amount must have been very small.

"My general conclusion is that most probably the actual rainfall was in excess of the recorded amount.

"The only unusual circumstance connected with this rainfall is its steady continuance for so long a period; and with regard to this fact the independent testimony of Mr. Sanmugam, the District Engineer, and of villagers at Kodalikkalla, seven miles to the north-east, is confirmatory. According to Mr. Sanmugam, the rain began at Kanukeni tank at about noon on the 15th, and lasted until afternoon on the 16th. I have myself at the Deduru Oya works measured an intensity of $1\frac{1}{2}$ in. per hour for five consecutive hours.

"At Kanukeni there is the evidence of the District Engineer, Mr. Sanmugam, at Kodalikkalla that of the villagers, at Nedunkeni that of the Medical Officer and Dispenser, that the heavy rain set in from the West. Towards evening the wind was blowing from the South, and on the following morning from the North-east, from which direction the wind was also recorded on the 15th morning at 9.30 a.m. Thus the storm was clearly cyclonic, as was to be expected, and the centre of the depression must have worked round from the north to the west of Nedunkeni. Regarding its earlier and later movements nothing is known."—*April* 16, 1898.

Whirlwind at Loughton, Essex, May 31, 1898.—On Tuesday, May 31, at about 4.15 p.m., I was in my garden, situated on high ground at Loughton, overlooking on the western side a large expanse of Epping Forest, when I observed a black cloud of peculiar shape and appearance travelling rapidly over the forest in the direction of my house. When first seen it was about three-quarters of a mile away, and I had only time to rush to the house, call

to my servants to close all windows, and make for my greenhouses, calling my gardener to close everything. I had only just got inside a strong teak fruit-house when the storm burst, and for a few seconds I thought the place would be blown down, as large conifers and cedars were bending over like fishing-rods, and huge branches of forest trees were whirled through the air. The atmosphere was dark with dust and leaves, but in a few seconds, perhaps 40, all was over, and I emerged from shelter to inspect the damage. The whole place was strewn with boughs, twigs, and leaves. A glass verandah in two sections was lifted bodily from its bed-plate, one half thrown on to some outbuildings to the north, the other half lay upside down in a building to the west. Loose lights 6 feet by 4 feet had been lifted off frames and pits and carried 30 or 40 yards: one must have passed over the buildings already referred to. Strange to say, not *all* the glass in some of the lights thus transported was broken. I lost one large copper beech, over 30 inches in circumference where it was broken off clean. A large lime over 30 feet high was completely destroyed: only the trunk remains. Two horse-chestnuts adjoining my boundary fence shared a similar fate, and in a field opposite an oak and a white hawthorn are now lying some yards from their respective trunks. At Loughton station, about half a mile away and 200 feet lower than my house, my son said when the train arrived he and the other passengers were unable to open the doors of the carriages for the force of the wind, and that large boughs were being carried some 100 feet over the station from the direction of my house. Several large trees have been blown down between my house and the station. As far as I can judge, at my own place the violence of the wind pressure only extended about 100 yards wide, nor have I been able to discover any damage over a greater length than half a mile. I should mention the shape of the cloud when I first observed it was that of an oblong body with frayed edges forming a tail as it were. That its action was that of a whirlwind is evidenced by the fact that most of the objects described a circular course, and were deposited in some cases in the rear or windward side of the point from which they started. Previous to the event the sky was bright and clear, after the cloud burst rain fell for several minutes and then the sun broke out and the conditions were the same as before. To show how very local was the area, many neighbours knew nothing at all about it, and would hardly credit that it could have taken place so near without their having seen or heard it. The vane on my stable was pointing due West at the time.—F. H. Faviell, *June* 6, 1898.

Winter Health Resorts.—Dr. A. Buchan in his recently published paper on the temperature of the British Islands for the 40 years 1856-95 (*Journal of the Scottish Meteorological Society*, 1898), in speaking of the temperature during the winter months, says:—

"It follows that where a winter climate is sought, offering, in the highest degree anywhere afforded by the British Islands, the combined qualities of mildness and dryness, such a climate is to be found on the shores of the Channel, from about Dover to Portland. To the west of Portland, and round the coast to Clifton, a higher temperature may be had, but the rainfall is greater, the climate damper, and raw weather of more frequent occurrence. On the other hand, in the eastern counties north of the Thames, the climate is as dry, or rather drier, but it is accompanied by a temperature from 2° to 3° colder.

"The South Coast has another climatic advantage which may be noted. The prevailing West-south-westerly winds having crossed the Isle of Wight, pass on in the direction of London. Now observations show that in passing from the Isle of Wight to London the mean temperature falls 3°, the lowering of the temperature being caused by the more rapid rate by which, as compared with the sea, the land is cooled by terrestrial radiation in winter. From this lower-

ing of the temperature on proceeding inland, it follows that haze and cloud are formed with greater frequency and of greater denseness as the winds successively advance on the colder districts. Hence the skies of the south coast may be expected to be clearer and brighter than in the valley of the Thames, a statement observation amply confirms.

"Various other districts in Wales, the North-west of England, and the West of Scotland might be named which offer no inconsiderable inducements as winter refuges, from their higher and more equable temperature at this season. All sanataria on the South and West Coasts have, as compared with inland places, this additional strong recommendation:—In such severe winters as those of 1814, 1820, 1838, 1855, 1860, 1867, 1870, 1874, 1878, 1881, and 1895, while the mean temperature has fallen at many inland places to from 9° to 13° below the average of the months, it has been observed that over extensive districts on the coast the temperature fell below the average only a third of these amounts. This great advantage of sea-coast localities will be better appreciated if there be kept in mind the great, and in many cases alarming, increase in the mortality from throat diseases which accompanies severe cold in winter; and it is to be noted that this advantage is enjoyed in a greater degree on the West Coast in localities which are well open to the Atlantic, than on the South Coast, which the comparatively narrow waters of the Channel less effectually protect.

"Since the averages of temperature given with this paper are all calculated for the same 40 years, this essential element of climate is therefore strictly comparable throughout. One important result is that all strong statements, such as are not infrequently made in favour of local climatologies, as regards their temperature, entirely disappear. It would be easy to find considerable differences of temperature among places, so that one place may seem to have a fine winter climate, quite its own, by selecting different years for the different places in striking the averages; but all such comparisons of local climates are worthless."

Rainfall at Johannesburg.—Mr. C. Aburrow, F.R.Met.Soc., the Town Engineer, in his Annual Report relating to the Public Works Department of the Stadsraad, Johannesburg, gives the following table of monthly rainfall and number of rainy days for the 9 years 1889-97:—

Month.	1889.		1890.		1891.		1892.		1893.		1894.		1895.		1896.		1897.	
	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.	Rainfall.	No. of Days.
	ins.		ins.		ins.		ins.		ins.		ins.		ins.		ins.		ins.	
Jan.	5·13	10	6·14	9	10·21	12	6·61	17	No record taken.	No record taken.	4·59	14	3·82	15	1·65	5	9·71	17
Feb.	3·15	7	3·47	8	8·09	12	5·11	11			7·16	16	4·57	9	3·71	10	4·99	10
Mar.	2·00	3	1·61	5	5·55	17	3·83	12			4·89	13	7·02	11	1·95	8	3·94	9
April	1·30	5	2·17	7	5·16	11	1·41	4			1·50	7	2·01	9	1·70	7	·56	5
May	...	0	...	0	1·12	7	1·09	5			2·79	9	·23	3	1·26	7	·53	2
June	...	0	...	0	·71	2	·09	1			·14	3	·12	1	·64	3	...	0
July	...	0	·75	3	...	0	...	0			...	0	...	0	...	0	...	0
Aug.	...	0	...	0	·56	1	...	0			·85	3	...	0	·79	5	·19	1
Sept.	1·00	5	·10	2	·05	1	2·03	9	2·76	6	2·32	10	·33	1	·45	3	·10	2
Oct.	·25	3	·18	3	1·44	8	3·68	13	2·45	12	·45	3	·06	2	2·40	7	3·27	13
Nov.	5·02	16	3·89	14	2·32	13	2·20	10	8·09	14	4·92	14	3·99	13	2·46	9	2·19	7
Dec.	2·00	10	7·63	18	5·64	15	1·49	12	5·51	16	5·80	13	6·99	12	6·22	18	3·50	14
Year	19·85	59	25·94	69	40·85	99	27·54	94	...	...	35·41	105	29·14	76	23·23	82	28·98	80

Meteorological Station on Mount Kosciusko, New South Wales.—Mr. Clement L. Wragge, of the Weather Bureau, Brisbane, informs us that on December 9, 1897, he established an experimental meteorological observatory on Mount Kosciusko, 7328 feet, the highest mountain in New South Wales; and by January 1, 1898, a similar station correlative thereto was also established near the sea-level at Merimbula, in New South Wales. Simultaneous observations are taken at both stations every four hours, commencing at midnight; and also, as a special series, half-hourly between 8 a.m. and noon, on the original Ben Nevis lines. Simultaneous readings are also taken at Sale, in Victoria, near the sea-level, and at Sydney, New South Wales. Simultaneous observations are further taken in Tasmania (with the exception of those at the half-hours) at Hobart, on the summit of Mount Wellington, and at the half-way station.

The principal donors to the Kosciusko scheme are Mr. R. Barr-Smith of Adelaide and the Hon. G. H. Reid, Premier of New South Wales, as representing the New South Wales Government.

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THE FREQUENCY OF RAINY DAYS IN THE BRITISH ISLANDS.

By ROBERT H. SCOTT, M.A., F.R.S.

[Read May 18, 1898.]

IT has been repeatedly urged to calculate the frequency with which rain is recorded, as a very desirable addition to the usual climatological records.

By general agreement, the definition of a "rainy day" is a day on which at least 0·01 inch of rain has been collected, so that in the list of rainy days several are included which do not merit the designation of "wet days."

The mode of treatment for the present paper has consisted in taking the number of rainy days in each month, and dividing that number by the total number of days in the month and ascertaining the resulting percentage. The figures quoted are all percentages.

It was decided to begin with the period 1876-95, and to take out the figures for all the stations appearing in the *Daily* and *Weekly Weather Reports* for that interval of 20 years. There are of these forty, and of these the several percentage figures for each month have been put down on the Maps, Figs. 1-12, and the yearly figures on Fig. 13. No attempt has been made to draw lines of equal frequency on these maps.

The list of stations is as follows :—

Aberdeen.	Glasgow.	London.	Shields.
Ardrossan.	Hastings.	Markree Castle.	Southampton.
Armagh.	Hereford.	Nairn.	Stonyhurst.
Cambridge.	Hillington.	Oxford.	Stornoway.
Cheadle.	Holyhead.	Parsonstown.	Strathfield Turgiss.
Churchstoke.	Hurst Castle.	Pembroke.	Sumburgh Head.
Donaghadee.	Jersey.	Plymouth.	Valencia.
Dublin.	Leith.	Roche's Point.	Wick.
Durham.	Liverpool.	Scarborough.	Yarmouth.
Falmouth.	Llandudno.	Scilly.	York.

It does not appear necessary to reproduce the monthly figures in tabular form, inasmuch as all the mean values are to be found on the monthly maps; but the monthly figures can be copied and deposited with the Society, if any wish is expressed that this should be done.

It may be interesting to note that during these twenty years, at these forty stations, there are only three cases of individual months with rain falling on every day. These were, for Stornoway, March 1882 and October 1893; and for Valencia, January 1877. Several cases occurred of months with only one day without rain, and, of course, numerous cases with only two or three.

As to the opposite extreme, of excessive dryness, all the records come from February 1891. In this month Cambridge reported 0. Six stations, York, Oxford, London, Hereford, Southampton, and Plymouth, reported 1. Five stations, Dublin, Scilly, Falmouth, Jersey, and Hurst Castle, had 2; and five stations, Leith, Shields, Llandudno, Churchstoke, and Cheadle, had 3 days on which rain fell.

We shall now proceed to describe the Maps seriatim. The first inspection shows us that the greatest excess of frequency is always on our Atlantic (the extreme north and west) coasts. The highest figures of all are found at Dunrossness (Shetland), and at Stornoway, in most months, but especially in the late autumn and winter. In summer the figures for the west of Ireland are higher.

In the four months, October to January inclusive, the value from Dunrossness reaches 80 and upwards, with a maximum of 85 in January. Stornoway does not touch 80 till November. At this period of the year the Irish stations do not reach 80, though Valencia comes very near it, with 79 in December.

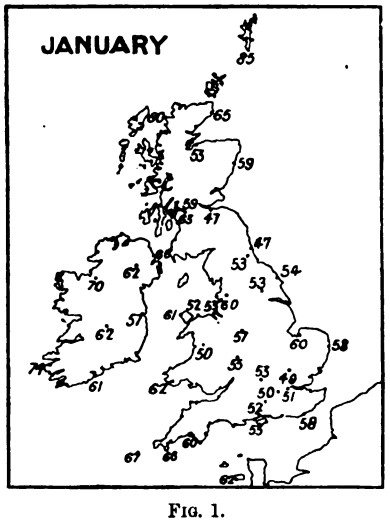


FIG. 1.

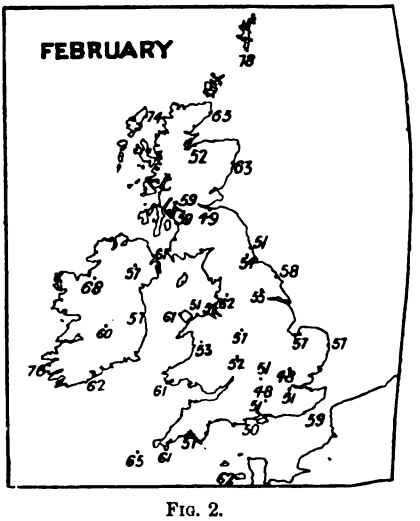


FIG. 2.

In January (Fig. 1) 70 appears in the west of Ireland, while the area of 60 and upwards embraces all the south coast of Cornwall, the extreme west of Wales, all Ireland, except Dublin, with Ardrossan

and also Stonyhurst and Hillington (Norfolk); of the rest, Shields, and Cambridge are the only places falling below 50.

February (Fig. 2) the distribution much resembles that of

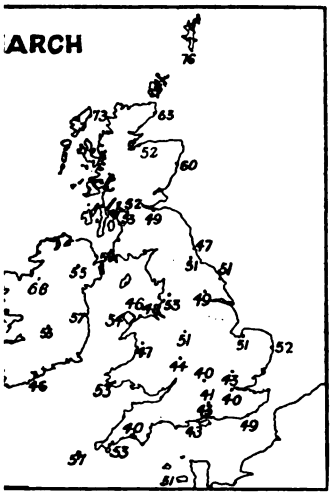


FIG. 3.

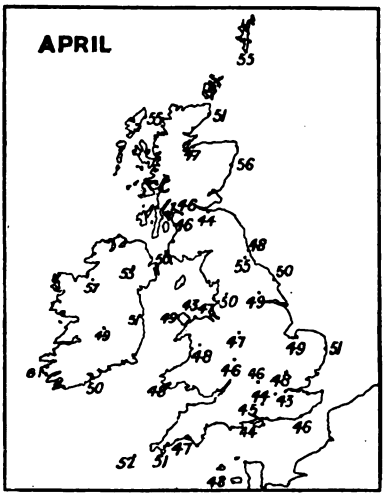


FIG. 4.

ry with figures slightly lower in most places, but decidedly so extreme north.

y March (Fig. 3) almost the whole of England has become much only a very few of the stations reaching 50.

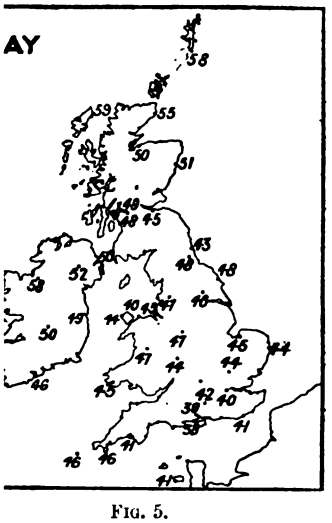


FIG. 5.

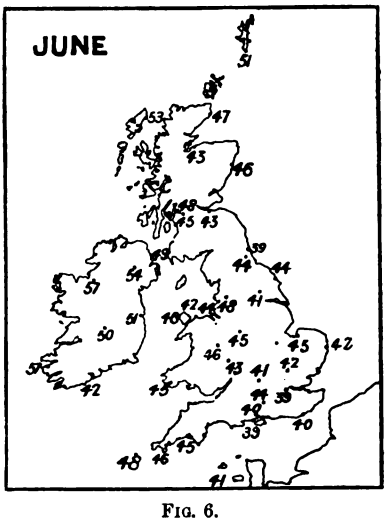


FIG. 6.

April (Fig. 4) the only place which reaches 60 is Valencia, and umbers are remarkably uniform.

May (Fig. 5) the lower values, below 40, begin to creep in over shire (at Southampton and Hurst Castle).

June (Fig. 6, p. 219) is the month with the least number of rainy days in the whole year, but in July the summer maximum of rain

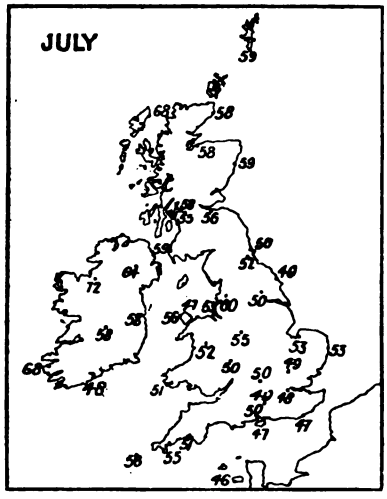


FIG. 7.

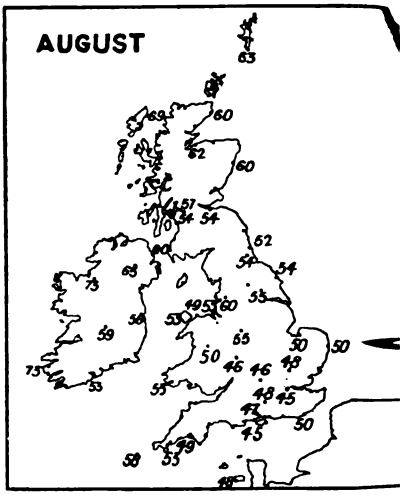


FIG. 8.

occurs, bringing the well-known Lammas Floods, and the figures again in Fig. 7, Markree (County Sligo) heading the list with 72.

August maintains the high level of July, but September show decided falling off, except at Stornoway and Dunrossness, indicatin

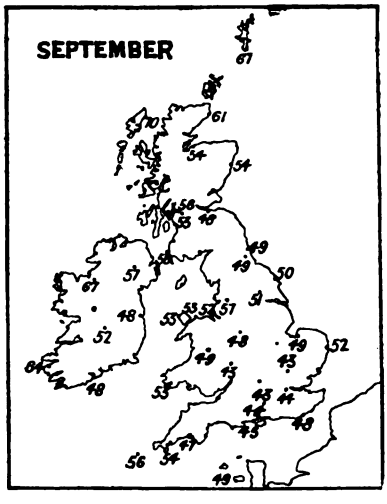


FIG. 9.

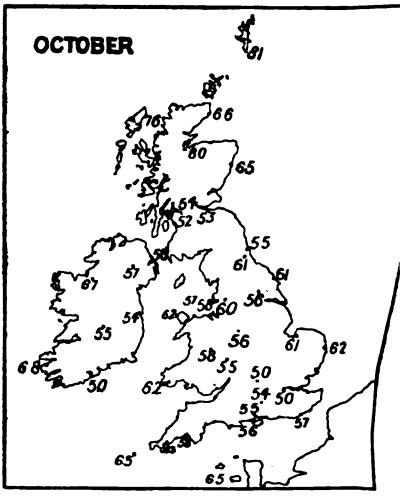


FIG. 10.

material improvement of weather, which is, however, only temporary, for October is wet again, especially in the extreme north and north-west.

This general description is borne out by taking the means of all the forty stations for the months from June to October. They are as follows :—June, 45·6; July, 54·4; August, 53·6; September, 48·0;

October, 58·9. If we look to England and Wales alone, with twenty-four stations, we find for June, 43·0; July, 51·3; August, 51·1;

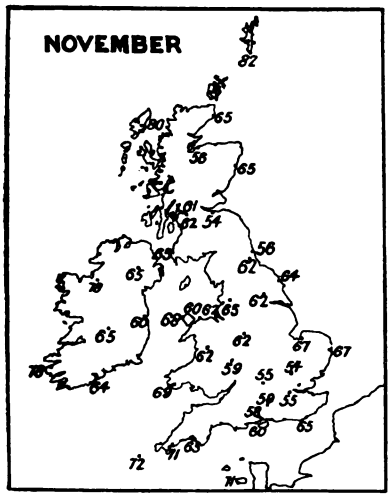


FIG. 11.

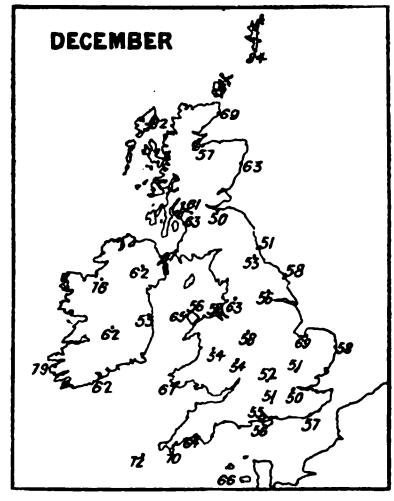


FIG. 12.

September, 48·8; October, 57·5. Accordingly, June and September are the two months with the best chance for days without rain.

We may here give a brief résumé of the results for the summer months. We see from the maps that the maximum of rainy-day frequency is found in the west of Ireland, offering a decided contrast to the winter distribution, when the maxima are found in the Hebrides and Shetlands.

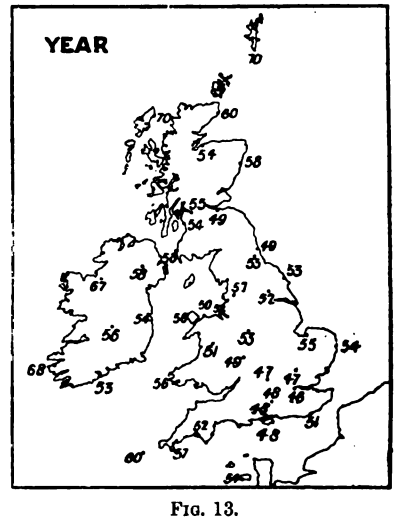


FIG. 13.

In October (Fig. 10) the weather becomes decidedly showery, and the distribution begins to assume its winter type, with the maximum in the north, Dunrossness having risen to 81 from 67, as already explained, being a change of 14 since September. This increase is only surpassed by that in Jersey, which amounts to 16, from 49 to 65. That there is a very general increase is proved by the fact that while in September only five stations showed values above 60, and several were below 50, in October seventeen stations passed the 60 limit, and no station fell below 50. The south-western stations also have considerable amounts, Jersey, Falmouth, and Scilly rising above 60 in this month, and above 70 in November.

In Jersey the figure of 71 for November is the maximum for the

year for that station, and it is interesting to see this when we remember that in that month the proportion of bright sunshine registered in Jersey is very low, being only 24 per cent, while Dublin registers 28 per cent. In almost all other months Jersey is far sunnier than other parts of the United Kingdom.[1] The deficiency of sunshine in Jersey

Sumburgh Hd
Wick
Gordon Castle
Nairn
Aberdeen
Dundee
Leith
Rosewell
Marchmont
Alnwick
N Shields
Durham
Scarborough
York
Wakefield
Spurn Head
Bawtry
Worksop
Belper
Yarmouth
Lowestoft
Cambridge
Geldeston
Aspley Guise
Hitchin
Berkhamsted
London
Margate
Dungeness
St Leonards
Worthing
Yentnor
Hurst Castle
Weymouth
Roaston
Exmouth
Torquay
Plymouth
Falmouth
Scilly
Guernsey
Jersey
Portsmouth
Southampton
Swanage
Stowell
Harestock
Arlington
Ilfracombe
Weston-super-Mare
Pembroke
St Davids
Roche's Pt
Valencia
Killarney
Waterford
Kilkenny
Parsontown
Dublin
Holyhead
Liverpool
Manchester
Chester
Buxton
Macclesfield
Prestwich
Stonyhurst
Blackpool
Douglas
Ramsey Jun
Augegarth
Rounton
Southwaite
Ushaw
Scaleby
Carlisle
Ardrossan
Rathesay
Greenock
Glasgow
Leith
Ochtertyre
Leanathe
Braemar
Aberfeldy
Fort William
Fort Augustus
Glencarron
Stornoway
Wick
Dunrobin
Malin Hd
Londonderry
Lissan
Edenfel
Armagh
Donaghadee
Belmullet
Markree Castle
Edgeworthstown
Kingstown
Valentia
Bantry
Cheadle
Strelley
Uppingham
Billingford
Churchstoke
Leighbro
Kenilworth
Hereford
Ross
Cwmcoed
Usk
Llandovery
Llandilo
Carmarthen
Brampford Speke
Budleigh Salterton
Clevedon
Bridgwater
Taunton
Ilminster
Yeovil
Sherborne
Dorchester
Wareham
Bournemouth
Ringwood
Salisbury
Andover
Basingstoke
Reading
Oxford
Aylesbury
Hitchin
Bedford
Peterborough
Lincoln
Gainsborough
Doncaster
Wakefield
Leeds
Bradford
Halifax
Huddersfield
Rochdale
Oldham
Manchester
Stockport
Macclesfield
Crewe
Nantwich
Whitchurch
Oswestry
Shrewsbury
Wellington
Wolverhampton
Walsall
Birmingham
Coventry
Rugby
Northampton
Bedford
Cambridge
Ely
Wisbech
Spalding
Boston
Grantham
Newark
Retford
Worksop
Mansfield
Nottingham
Derby
Burton
Uttoxeter
Stafford
Stoke
Leek
Buxton
Matlock
Chesterfield
Sheffield
Barnsley
Pontefract
Selby
York
Malton
Scarborough
Whitby
Middlesbrough
Stockton
Darlington
Durham
Newcastle
Morpeth
Berwick
Greenlaw
Hawick
Jedburgh
Kelso
Coldstream
Duns
Dunbar
North Berwick
Haddington
Edinburgh
Linlithgow
Falkirk
Stirling
Callander
Crieff
Perth
Dundee
Arbroath
Montrose
Aberdeen
Banff
Elgin
Nairn
Inverness
Fort George
Fort Augustus
Fort William
Oban
Tobermory
Islay
Campbeltown
Ardrossan
Ayr
Girvan
Stranraer
Portpatrick
Wigtown
Whithorn
Kirkcudbright
Dumfries
Lockerbie
Moffat
Langholm
Carlisle
Penrith
Appleby
Kendal
Lancaster
Preston
Blackburn
Bolton
Wigan
Warrington
Chester
Holyhead
Bangor
Carnarvon
Pwllheli
Barmouth
Aberystwith
Machynlleth
Newtown
Welshpool
Llangollen
Ruthin
Denbigh
Rhyl
Colwyn Bay
Llandudno
Conway
Bangor
Menai Bridge
Holyhead
Amlwch
Beaumaris
Carnarvon
Pwllheli
Barmouth
Aberystwith
Cardigan
Tenby
Milford Haven
Haverfordwest
Fishguard
Newport
Cardiff
Penarth
Barry
Bridgend
Neath
Swansea
Llanelly
Carmarthen
Llandilo
Llandovery
Brecon
Builth
Rhayader
Llandrindod
Knighton
Ludlow
Bridgnorth
Shifnal
Newport
Stafford
Rugeley
Lichfield
Tamworth
Atherstone
Nuneaton
Leicester
Loughboro
Melton Mowbray
Oakham
Stamford
Bourne
Sleaford
Horncastle
Louth
Grimsby
Cleethorpes
Barton
Gainsborough
Scunthorpe
Market Rasen
Lincoln
Newark
Southwell
Retford
Worksop
Mansfield
Chesterfield
Matlock
Ashbourne
Derby
Nottingham
Loughboro
Leicester
Rugby
Daventry
Towcester
Buckingham
Aylesbury
Tring
Watford
Hertford
Bishop's Stortford
Saffron Walden
Newmarket
Bury St Edmunds
Thetford
Swaffham
Fakenham
Wells
Cromer
Norwich
Yarmouth
Lowestoft
Southwold
Aldeburgh
Woodbridge
Ipswich
Colchester
Maldon
Chelmsford
Brentwood
Romford
Epping
Hertford
Hitchin
Luton
Dunstable
Aylesbury
Thame
Wallingford
Abingdon
Oxford
Witney
Chipping Norton
Moreton-in-Marsh
Stow-on-the-Wold
Cheltenham
Gloucester
Tewkesbury
Evesham
Pershore
Worcester
Droitwich
Kidderminster
Bewdley
Bridgnorth
Shifnal
Wellington
Shrewsbury
Oswestry
Whitchurch
Nantwich
Crewe
Macclesfield
Stockport
Manchester
Rochdale
Oldham
Bolton
Wigan
Warrington
Chester
Holyhead
Bangor

mouth, 58, is very striking, and not easily explicable, as it occurs in this month only.

The map for the year (Fig. 13, p. 221) exhibits the highest figures, 70, in the extreme north, while all the Atlantic coasts, from Scilly up to the Pentland Firth, reach 60. Over England and Wales the values are,

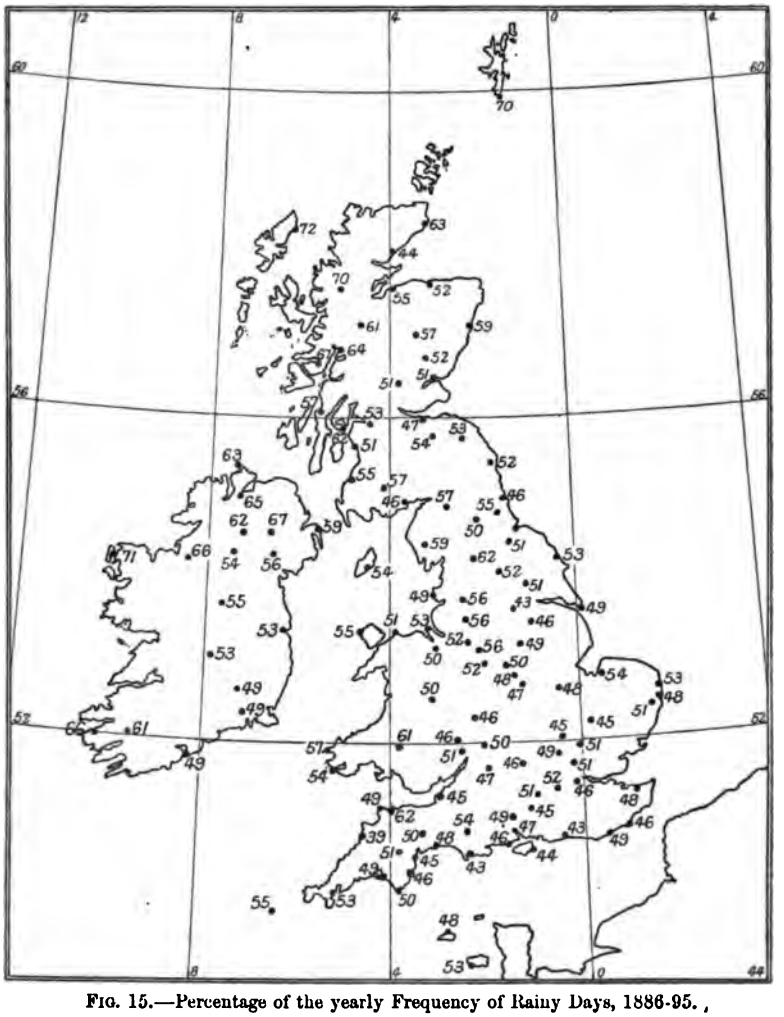


FIG. 15.—Percentage of the yearly Frequency of Rainy Days, 1886-95.

as a whole, fairly uniform. Leith and Shields come out as dry with 49, while all the South, Midland, and South-eastern stations, except Hastings, exhibit figures below 50.

As the figures on these Maps are manifestly insufficient to indicate the distribution of rainy days over the country in a satisfactory manner, an attempt has been made to improve the representation by reducing the number of years for which the data have been employed. The decade 1886-95 has been taken, and for this 120 stations have been

utilised. It is hoped that this number may give a fair approximation to the general features of the distribution, although 120 is but a small fraction of the total of upwards of 3000 stations at which rain is measured in these islands. However, at some of the most interesting stations, on mountains, the gauges cannot be examined daily, so that the number of days with rain is not always obtainable.

As Mr. Symons gives, for all stations for which the information has reached him, the total number of rainy days in the year, it would have been possible to have submitted to the Society the figures for 1200 stations in place of those for one-tenth of that number; but it will be seen from the Map (Fig. 15) that the distribution is remarkably uniform, so that multiplication of data has not seemed necessary, for we are not trying to go into the incidence of rainy days in individual valleys.

The names of the stations with the ten yearly totals and the percentages are given in the Table, and the positions in Fig. 14. The percentages for the different stations are given on Fig. 15.

There are only four of the values on this map which reach 70, viz. those for Belmullet, Glencarron, Stornoway, and Dunrossness, all of them on the Atlantic coast. Then come the stations with 60 and upwards, and these lie on a belt stretching from south-west to north-east. The only spots outside this belt which attain this figure are Hawes Junction, Llandovery, and Arlington Court, near Barnstaple. It is not a little remarkable that Seathwaite, with an annual fall of 136 inches, only shows the figure of 59 for rain frequency, while Stornoway, with 45 inches, shows a frequency of 72. It is therefore clear that the individual showers must be heavier in the Lake Country than in the Hebrides.

The rest of the stations are pretty evenly divided between the forties and the fifties. The lowest number of all is 39 for Bude, which is very remarkable as there is no other place with so low a value anywhere near it.

Inspection of the Map shows certain discrepancies. Thus Dunrobin has 44 when Wick, near it, has 63. Similarly Ilfracombe has 49, while Arlington Court has 62. In these two cases the dryness of the lower station seems to be due to a sort of *Föhn* action. Dunrobin lies on the east coast with the Sutherland hills to the westward, and Ilfracombe is nestled under the ridge, the prolongation of Exmoor, on which Arlington Court is situated. The figure for Wakefield, 43, is also low as compared with those for Stonyhurst, Prestwich, and Buxton, but Bawtry supports it with 46. A line of values just above 50 stretches, on the north-west side of London, from Bennington to Strathfield Turgiss, the precise reason for which is not very obvious. The south-east of Ireland is below 50, and so is the south coast of England, to the eastward of Start Point, as well as the Midland counties, if we except Cheltenham and Ross.

I hope that the Society will recognise that this is only a first attempt at recording the frequency of rainy days in these islands, but it is sufficient to throw some considerable light on the subject of the frequency with which rain falls, and to disprove absurd statements, such as that made in a treatise on Meteorology published in 1881, in a foreign capital, which is as follows :—

"It has been established that in the city of Manchester, since the great increase in its factories, hardly a day passes without rain." The figure for Prestwich is 56, so that not much more than half the days in the year bring any rain to Manchester.

I would only conclude this brief paper by saying that I am much indebted to Mr. F. Gaster and Mr. A. J. Rigby for assistance in its preparation.

YEARLY TOTALS AND PERCENTAGE OF RAINY DAYS AT 120 STATIONS FOR THE 10 YEARS 1886-95.

Stations.	Totals.	Per-centage.	Stations.	Totals.	Per-centage.
Aberdeen	2171	59	Glenlee	2090	57
Alnwick Castle	1904	52	Gordon Castle	1888	52
Ardrossan	1854	51	Guernsey	1761	48
Arlington	2265	62			
Armagh	2062	56	Harestock	1774	49
Aspley Guise	1657	45	Hastings	1795	49
Aysgarth	1889	52	Hawes Junction	2281	62
			Hereford	1694	46
Bawtry	1662	46	Hillington	1981	54
Belmullet	2582	71	Hodsock	1772	49
Bennington	1866	51	Holyhead	2022	55
Belper	1811	50	Hurst Castle	1687	46
Berkhamsted	1794	49			
Blackpool	1782	49	Ilfracombe	1776	49
Braemar	2068	57			
Brampford Speke	1849	51	Jersey	1948	53
Brookeborough	1980	54			
Bude	1438	39	Kenilworth	1685	46
Buxton	2049	56	Kilkenny	1807	49
			Killarney	2229	61
Calton Mor	2084	57			
Cambridge	1640	45	Laudale	2429	67
Cargen	1671	46	Lednathie	1904	52
Cheadle	1891	52	Leith	1727	47
Cheltenham	1817	50	Lissan	2458	67
Chester	1831	50	Liverpool	1941	53
Churchstoke	1835	50	Llandovery	2226	61
Cirencester	1705	47	Llandudno	1852	51
Cooper's Hill	1886	52	London	1667	46
Cullompton	1837	50	Londonderry	2363	65
			Loughborough	1728	47
Donaghadee	2167	59	Lowestoft	1744	48
Douglas	1990	54			
Dublin	1920	53	Macclesfield	1882	52
Dundee	1879	51	Malin Head	2285	63
Dungeness	1671	46	Marchmont	1950	53
Dunrobin	1602	44	Margate	1770	48
Durham	2002	55	Markree	2421	66
Edenfel	2268	62	Nairn	2023	55
Edgeworthstown	2000	55			
			Ochtertyre	1875	51
Falmouth	1945	53	Oxford	1665	46
Fort Augustus	2244	61			
Fort William	2345	64	Parsonstown	1921	53
			Pembroke	1971	54
Geldeston	1878	51	Pinmore	1999	55
Glasgow	1927	53	Plymouth	1802	49
Glencarron	2564	70	Prawle Point	1834	50

YEARLY TOTALS AND PERCENTAGE OF RAINY DAYS AT 120 STATIONS FOR THE 10 YEARS 1886-95—*Continued.*

Stations.	Totals.	Per-centage.	Stations.	Totals.	Per-centage.
Prestwich	2052	56	Strelley	1763	48
			Sumburgh Head	2562	70
Roche's Point	1797	49	Swarraton	1639	45
Rosewell	1989	54			
Ross	1876	51	Teignmouth	1646	45
Rothamsted	1874	51	Torquay	1687	46
Rothesay	2260	62			
Rounton	1880	51	Uppingham	1757	48
Rousdon	1766	48	Ushaw	1836	50
Scaleby	2080	57	Valencia	2413	66
Scarborough	1942	53	Ventnor	1618	44
Scilly	2014	55			
Seathwaite	2141	59	Wakefield	1581	43
Shields	1666	46	Waterford	1792	49
Southampton	1699	47	Weston-super-Mare	1646	45
Spurn Head	1787	49	Weymouth	1573	43
St. Davids	2095	57	Wick	2318	63
Stonyhurst	2031	56	Worthing	1561	43
Stornoway	2619	72			
Stowell	1966	54	Yarmouth	1945	53
Strathfield Turgiss	1859	51	York	1850	51

DISCUSSION.

The President (Mr. F. C. BAYARD) said that the Society was indebted to Mr. Scott for his paper, which, he was sure, would be productive of much discussion. He was surprised that no reference had been made to the influence of elevation above sea-level upon this question, which must, he thought, be considerable. It certainly would seem so in the case of Ilfracombe and Arlington Court, which was a good instance of the relation of varying height to days of rain.

Mr. W. LYON remarked that in Manchester rainy days were supposed to be so frequent that sunshine was almost looked upon as a phenomenon.

Capt. A. CARPENTER thought that there was more justification in the statement that it rained every day in Manchester than appeared in Mr. Scott's paper. In manufacturing towns the sun is almost always obscured by smoke haze, and the smoke particles fall back to earth laden with moisture that has condensed on them, thus making the air always feel damp, the streets always wet and grimy, and giving all the sensations of a wet day. This fine shower of damp-laden smoke would not record ·01 in. per diem. It was noticeable that the line of values just above 50, referred to at the end of the paper, followed approximately the great chalk formation stretching from Salisbury to Norwich.

Mr. B. LATHAM said the paper was of undoubted value, but he should have liked to have seen it in greater detail. With regard to the relation of the height above sea-level upon rainfall, the question had been studied by himself, and also worked up by Mr. Eaton, and the relation was found to be of a very decided character, both the amount of rain, and the number of rainy days, increasing with elevation. What he should like to see, and what would be of incalculable benefit to the engineering profession, would be an analysis of the hourly falls, showing the rate at which rain was precipitated. He did not

think that the total duration of rainfall during the whole of an average year would in any case amount to more than three weeks if all the time it fell was added together. It was to be deplored that the Government were so strictly economical in these matters. There was valuable material, but it was lying idle, which was a most unsatisfactory condition of things, especially when Calcutta and other Colonial observatories gave the results in a form that was useful.

Mr. F. J. BRODIE said that one of the most interesting and at the same time surprising features suggested by the paper seemed to him to be the absence of any close relation between the frequency and the amount of rain. In January, for example, the frequency at Stornoway is 80, and at Sumburgh Head 85; but when the amount was considered it appeared that the state of things was entirely reversed, Sumburgh Head having an average fall of less than 4 ins. while Stornoway had more than 5 ins. Again, in the months of May and June the average quantity of rain at Sumburgh Head was practically the same as in London. At the northern station, however, the frequency values were respectively as high as 58 and 51, while in London they were only 40 and 39. From these facts it was quite clear that a "rainy day" meant a very different thing in different parts of the country, and that in order to get the best value from the information just placed before the Society we must combine it with averages showing the amount recorded at the various stations.

Mr. H. N. DICKSON hoped the investigation would be continued. He thought in a question of this kind the type of rain should be studied, especially with regard to the relations existing between the summer rainfall of the eastern counties and the cyclonic rainfall of the west coast. He should also like to have seen allowance made for the geographical characteristics of many of the stations.

Mr. G. J. SYMONS heartily supported Mr. Latham in his remarks emphasising the advisability of stimulating the working up of the results of the self-recording rain gauges. There was no country which had such material, but it was not available for practical purposes. He was pleased to see that some definite conclusion could be drawn as to the frequency of rainy days. Years ago the definitions were so unsatisfactory and so varied, that he almost resolved to omit the column from *British Rainfall* altogether. It was a testimony to the attention and efficiency of an observer when there was a good percentage of small amounts in his record, as showing the regularity of his visits to the gauge. Mr. Scott's reference to the Lake District thoroughly corroborated what he (Mr. Symons) had so often said, viz. that though it was the wettest district in the British Isles, that was due to the heavy nature of its rainfall rather than to its frequency, and the district would compare favourably with other parts of the country for sunshine and fine weather. In conclusion, he expressed his desire to see an analysis of the automatic records maintained for so many years by the Meteorological Office, and supplemented if possible by others, so that we might have authoritative information with regard to hourly falls.

Mr. J. HOPKINSON said that he quite agreed with Mr. Symons as to discrepancies in entries of wet days being mostly owing to what he might term the "personal element" in rainfall observations. Out of 44 observers reporting to the Hertfordshire Natural History Society whose returns of the amount of rain he could accept for publication, he was obliged to omit the number of days of rain given by 4 of them, because they evidently only looked at their gauges when they thought that rain had fallen. He had endeavoured to get every observer to examine his gauge daily. The annual average for Hertfordshire for the 27 years 1870-96 was 168 days, or 46 per cent, which closely agreed with that shown on one of Mr. Scott's maps; but his own observations for the 10 years 1877-86 at Watford gave 184 days, and for the 10

years 1887-96 at St. Albans, 183 days, in each case about 50 per cent, and he thought that the difference between his own results and the mean for Hertfordshire was chiefly due to some of the observers disregarding small falls of rain. He hoped that Mr. Scott would deposit in the Society's library, as he had offered to do, the figures which he had worked out for each station, as they would be useful to any one who might undertake to carry on the investigation at some future time.

Mr. R. C. MOSSMAN remarked on the small number of rainy days for Leith. He had no knowledge of the observer or of the gauge, but comparing it with surrounding stations, even with one as near as a mile and a half, the lack of wet days was most marked.

Mr. W. MARRIOTT said that on looking at the table of yearly totals and percentages the low values for Bude were very striking. He had been under the impression that the gauge was not visited regularly each day. A correspondence with the observer respecting this question was met by the reply: "Please do not compare other places such as Newquay and Ilfracombe with Bude in the matter of rainfall. As I have told you before, people are often wearing their mackintoshes at the above places when the ladies are revelling in their sunshades at Bude." The nearest station in Mr. Scott's paper with which to compare Bude in respect of distance would be Arlington Court, though in respect of altitude the comparison would not be so favourable, the latter being at an elevation of some 600 feet. The figures were, however, widely different. In his opinion, both altitude and geographical position with respect to certain winds were factors to be considered in an inquiry of this kind. He thought a possible solution of the markedly high value for Hillington during the month of December was that the observer—a particularly careful one—collected a large amount of moisture in the form of dew, mist, or hoar frost; and it was perfectly correct, according to the rules laid down by Mr. Symons, to call such a "rainy day," always providing the total reached the proper measurable amount. [When inspecting the station at Bude in September 1898, I found that the observer had not examined his rain gauge *every day*, and consequently his number of rainy days is incorrect.—W. M.]

Mr. W. H. TINGEY remarked that in his experience it was possible for two observers to differ as much as from ·005 in. to ·007 in the reading of rainfall amounts, by reason of capillary attraction making the exact quantity uncertain.

Mr. R. H. SCOTT, in reply, said that he considered the number of years and stations far too limited to supply information as to the influence of altitude on the results, for there were only 40 stations for the 20-year period and 120 for 10 years. He should like to know from Mr. Latham and Mr. Symons in what form they wanted the hourly results of rainfall to be published. The hourly values had been lithographed or printed for many years (from April 1874 to December 1886) some time ago, and since that date hourly totals for five-day periods had been and were still being published, but nobody seemed to use them in any way. He would undertake that if any suggestion on the subject were formulated by the Council of the Society that it should be duly laid before the Meteorological Council. He was now dealing with 20 years' observation of hourly rainfall, but one great difficulty to contend with was the occasional breaking of the records through the stopping of the clock, falls of snow, etc. With reference to the situation of the gauge at Leith, it was in a corner of the bowling-green in an enclosed space. The observer was the telegraphic reporter for the town. With regard to what Mr. Marriott had said with respect to the high mean for Hillington in December being due to the inclusion of rime, mist, etc., he thought if this suggested explanation held good the difference should be as strongly marked in other months, say November and January, as in December.

THE ABNORMAL WEATHER OF JANUARY 1898.

By FREDERICK J. BRODIE, F.R.Met.Soc.

[Read May 18, 1898.]

OVER the United Kingdom, and probably in adjacent parts of the Continent also, January 1898 was one of the most remarkable winter months on record.

In all but the extreme northern and north-western portions of the kingdom, where, for reasons that will be shown presently, the weather was fairly normal, the month was distinguished in the first place by a striking absence of storms, either of wind, rain, or snow. At some stations on the east and south coasts of England the wind only once reached the strength of even a moderate gale, while at many other places in the same districts it never blew with a force exceeding 6 on the Beaufort Scale.

Except at a few places in the north-west of England and in the west and north of Scotland, the month was singularly dry, many stations in the west and south of England reporting far less than one-fourth of the average amount of rain. At a large number of places situated in the eastern and southern portions of the kingdom, the total fall was the smallest measured in January since the year 1880, and at some places, such for example as Hereford, Cirencester, Southampton, and Hurst Castle, it was the smallest shown in the Meteorological Office records, extending back to the year 1866. At Marchmont, again, in Berwickshire, last January was the driest since the record commenced in 1868, while still farther north, at Wick, it was by far the driest since 1867.

Over the greater part of the kingdom the month was further distinguished by an absence of snow or sleet,—a somewhat unusual feature in January even for any individual station, but far more remarkable as applying to the country as a whole. It is still more singular to note that while most stations in the north presented in this respect a clean record, the phenomenon was reported in two localities in which it might least have been expected. On the 9th of the month a little sleet fell at St. Mary's, Scilly, while on the following day snow was seen at St. Aubin's, Jersey, the thermometer in each place and at each time standing at or very little below 50°!

The most remarkable feature in the weather of January 1898 was, however, without doubt, the striking absence of severe frost, the frequent prevalence of unusually mild weather, and, as a result, the abnormal warmth of the month, especially in the more northern parts of the kingdom. The leading facts relating to the temperature of January are shown, first, in the accompanying table, which gives for a large number of stations situated in various parts of the country the highest and lowest readings observed, the mean of the maximum and of the minimum readings taken separately, and the mean of the two combined, with the difference from the average, deduced from observations extending in most cases over the 25 years 1871-95.

Except for a day or two about the middle of the month, when rather low temperatures prevailed in the south-east of England, the weather could at no time have been described as cold for the time of

year, the thermometer falling in very few cases more than three or four degrees below the freezing point. At many coast stations in the west and south it never went below 32°, while at some few places in the

TABLE I.—Temperatures observed in the British Islands during January 1898.

Stations.	Highest Observed.	Lowest Observed.	Mean of Daily Maxima.		Mean of Daily Minima.		Mean of Max. and Min. Combined.	
			Mean.	Difference from Average.	Mean.	Difference from Average.	Mean.	Difference from Average.
England and Wales.								
Alnwick Castle	56	30	49·9	+8·6	38·6	+5·5	44·3	+7·1
North Shields	58	33	49·8	+7·1	39·3	+5·8	44·6	+6·5
York	58	29	48·4	+6·2	38·1	+6·2	43·3	+6·2
Yarmouth	55	30	46·6	+5·7	38·0	+5·0	42·3	+5·3
Cambridge	57	28	48·1	+5·4	36·7	+5·8	42·4	+5·6
Cheadle	56	31	46·0	+5·5	38·2	+6·6	42·1	+6·0
Loughborough	59	29	48·0	+5·5	37·7	+6·0	42·9	+5·8
Hereford	59	28	48·3	+5·0	37·9	+5·4	43·1	+5·2
Oxford	55	30	47·5	+5·0	39·2	+6·3	43·4	+5·7
London	55	29	47·7	+4·3	38·9	+5·7	43·3	+5·0
Hastings	54	32	47·8	+5·0	41·0	+6·1	44·4	+5·5
Southampton	55	30	49·0	+5·2	41·2	+6·7	45·1	+5·9
Isle of Man (Douglas)	55	32	50·1	+6·0	43·4	+7·2	46·8	+6·6
Stonyhurst	53	32	46·8	+5·1	40·3	+7·6	43·6	+6·4
Liverpool	58	32	49·0	+6·0	40·9	+6·2	45·0	+6·1
Holyhead	52	38	49·5	+4·4	43·6	+5·4	46·6	+4·9
Pembroke	52	30	49·3	+4·2	44·9	+5·9	47·1	+5·0
Cullompton	55	28	49·3	+5·3	39·7	+5·0	44·5	+5·1
Falmouth	54	39	50·8	+4·2	45·3	+5·7	48·1	+5·0
Scilly (St. Mary's)	56	42	52·5	+4·0	46·5	+4·2	49·5	+4·1
Jersey (St. Aubin's)	54	32	49·1	+3·5	40·8	+2·9	45·0	+3·2
Scotland.								
Wick	60	29	47·9	+5·9	37·3	+4·4	42·6	+5·1
Lairg	57	23	46·6	+5·3	36·2	+4·9	41·4	+5·1
Aberdeen	59	30	47·9	+5·9	37·1	+4·3	42·5	+5·1
Braemar	52	23	44·5	+5·1	35·3	+6·8	39·9	+5·9
Ochtertyre	55	28	48·4	+6·8	37·2	+6·1	42·8	+6·4
Leith	58	31	50·4	+6·5	39·1	+5·8	44·8	+6·2
Sumburgh Head	52	31	46·9	+4·4	39·5	+4·3	43·2	+4·3
Stornoway	53	30	47·5	+4·6	38·3	+4·3	42·9	+4·4
Fort William	54	32	47·8	+4·6	40·7	+7·3	44·3	+6·0
Glasgow	53	31	47·5	+5·4	41·1	+7·3	44·3	+6·3
Glenlee	54	28	48·1	+6·3	38·9	+6·9	43·5	+6·6
Ireland.								
Donaghadee	58	33	49·7	+5·5	41·4	+5·6	45·6	+5·6
Armagh	56	31	49·0	+6·1	40·8	+6·9	44·9	+6·5
Dublin	61	32	51·6	+6·1	43·9	+7·1	47·8	+6·6
Parsonstown	57	30	50·0	+5·0	40·4	+6·8	45·2	+5·9
Kilkenny	58	30	50·1	+4·3	41·6	+6·3	45·9	+5·3
Roche's Point	55	37	51·5	+4·2	45·7	+6·8	48·6	+5·5
Londonderry	55	32	48·8	+4·5	40·8	+6·0	44·8	+5·2
Markree Castle	56	28	49·0	+4·5	40·0	+6·4	44·5	+5·4
Belmullet	54	34	50·0	+3·6	43·0	+4·3	46·5	+3·9
Foynes	57	32	51·1	+5·0	42·5	+6·9	46·8	+5·9
Valencia Island	55	35	51·6	+2·6	45·6	+5·8	48·6	+4·2

same localities it scarcely fell below 40°. A comparison with the records of previous years shows that over the United Kingdom as a whole the absence of severe frost was more marked than in any January since

1884, and that in many parts of Scotland it was without parallel in the Meteorological Office records, extending back in most cases for 25, and in some instances for 30 years. In Edinburgh the thermometer did not quite reach the freezing point, the absolute minimum of 32°·3 on the 5th being much higher than any previously registered in January since the commencement of the record in 1840. In no other year of the series did the thermometer in January fail to go below 30°. Among the frequent spells of warmth experienced during the month there were two which stood out with distinct prominence. The first of these occurred on or about the 19th, when the thermometer rose to 55° and upwards at a large number of stations situated in all parts of the country, the highest reading of all (60°) being recorded, singularly enough, in the north of Scotland, at Wick. At many stations in the western and northern districts the readings at this time were in excess of anything recorded in January for at least 25 years, and at Edinburgh, where the thermometer reached 56°·5, the reading was the highest observed in January since 1846. The second burst of abnormal heat occurred on the 30th. In Scotland the readings were scarcely so high as those of the 19th, but at many of the English and Irish stations they were even higher, and in several cases were again the highest observed in January for more than a quarter of a century past.

The mean temperatures for the month given in the table show an enormous excess of warmth over the whole kingdom. With the exception of two or three stations in the extreme west and south-west, the mean readings were at least 5° above the average; while at many places situated in the more northern parts of the United Kingdom they were more than 6° above it, the excess at one station (Alnwick Castle) amounting to rather over 7°. In the north-eastern districts—relatively the warmest in the whole kingdom—the excess of heat appears to have been greater in the daytime than at night, but in all other regions an opposite state of things prevailed, the undue warmth of the nights being especially noticeable at some of the western stations.

A comparison with previous years shows that over the southern parts of England the month, as a whole, was not so mild as the January of 1884, and that in some few places, including London, it was slightly cooler than January 1877. Over the northern parts of the kingdom, however, the records fail to show anything like so mild a January. The longest series of observations available for the purposes of comparison appears to be that recently collected by Mr. R. C. Mossman, and published in his valuable paper on the climate of Edinburgh. The detailed analysis of temperature, from which we have already quoted, does not go farther back than the year 1840, but the record of monthly means extends as far as the year 1764. Since then there has been no January in Edinburgh with so high a mean temperature as that recorded in the month under review. Last January the mean value was 44°·6, the nearest approach to so high a mean being in 1796, when the reading was 43°·8. During the whole period of 134 years covered by the record there were only two cases in which the January mean temperature exceeded 42°, and only 17 cases in which it even exceeded 40°.

The general distribution of temperature over our islands in a normal January, and in that of the present year, is shown by the accompanying

isothermal maps, the normal charts being drawn from the average values for the 25 years 1871-95, recently published by the Meteorological Office. Figs. 1 and 2 give the monthly mean temperature as derived from the maximum and minimum readings, Figs. 3 and 4 (p. 233) the mean of the daily maxima alone, and Figs. 5 and 6 (p. 234) the mean of the daily minima. The values have in all cases been corrected for height above sea-level.

An examination of Fig. 1 shows that in a normal January the highest mean temperatures are experienced on our extreme south-

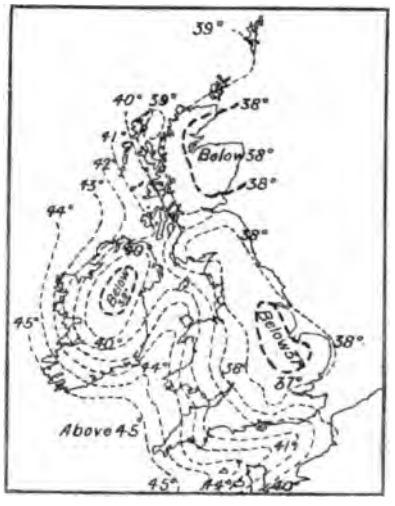


FIG. 1.—Average Mean Temperature, January.

FIG. 2.—Mean Temperature, January 1898.

west coasts, the genial influence of the warm Atlantic waters being further shown by the manner in which the isotherms trend northwards over the St. George's Channel and even over the Irish Sea. For this reason the Isle of Man enjoys in January a temperature practically as high as that of the Isle of Wight, the mean reading in Douglas being quite 2° higher than at places in a similar latitude in the north of Ireland, and quite 3° higher than at similar latitudes in the north of England. The coldest weather in January is found not, as one might suppose, in Scotland, but in the east of England, the mean temperature over Lincolnshire and portions of the neighbouring counties being below 37°. Next to this come the eastern and central parts of Scotland with a mean temperature below 38°, and next again the central parts of the north of Ireland with a mean below 39°. In all the western and southern districts the weather on the coast is far milder than at adjacent inland stations, but in the east of England the difference is extremely slight, while in the east of Scotland it fails to exist, the North Sea waters at this time of the year being sufficiently cold to obliterate the usual differences between land and sea temperatures.

A rough glance at Fig. 2 reveals very little disparity between the normal isotherms and the state of things prevailing in January 1898. The values are, of course, much higher, and the thermal gradient in the

west and south is less steep, but the highest temperatures are still found in the south-west, while the areas of cold over England and Ireland retain almost precisely their normal positions. In the chart for January 1898, however, the east of England is not colder than the north and north-east of Scotland; while in the north of England and south of Scotland the weather is relatively warm, the isotherm of 45° extending well across the Border country.

In Fig. 3, giving the normal distribution of the mean maxima in January, the isotherms are far more open than in the case of the mean

FIG. 3.—Average Mean Maximum Temperature, January.

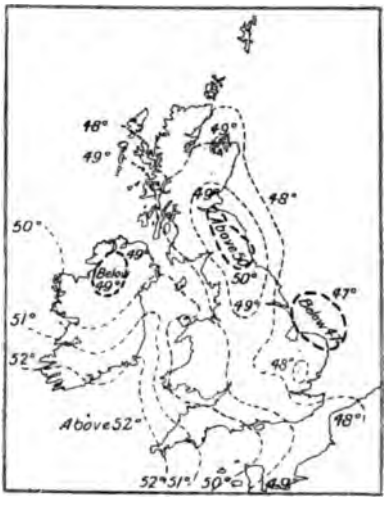


FIG. 4.—Mean Maximum Temperature, January 1898.

temperature; and while the highest readings are still found in the south-west, the three areas of cold all lie farther to the eastward, the lowest temperatures of all being reported on the coasts of Lincolnshire and Norfolk.

In this case the map of actual values for January 1898 (Fig. 4) shows a very marked difference from the normal. Over the southern parts of the kingdom the isotherms are not dissimilar, but in the north-east there is a very decided patch of warmth, the mean maximum readings at sea-level stations in Berwickshire and Northumberland being slightly above 50°. The values in this region were, in fact, from 7° to 9° above the average for January, and only 1° or 2° below the average for the month of April.

The charts of mean minimum temperature (Figs. 5 and 6, p. 234) tell very much the same tale. At night, owing to brisk terrestrial radiation, the difference between the land and sea temperatures is usually very great, and in each map we see that the isotherms lie more closely together than in the case either of the mean daily or of the mean maximum readings. Over the western and southern portions of the kingdom the difference between the charts of normal and actual values is again slight. Over Scotland, however, the area of cold usually existing over the central

districts lies out farther to the eastward, while in the north of England the frost belt, shown in the average chart, is altogether wanting.

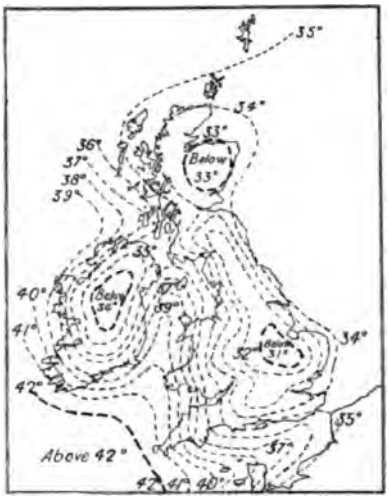


FIG. 5.—Average Mean Minimum Temperature, January.

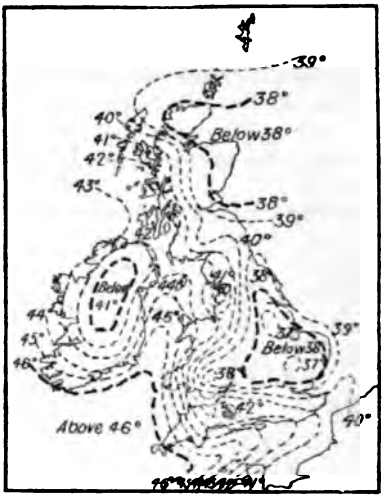


FIG. 6.—Mean Minimum Temperature, January 1898.

With the exception of some modifications in detail, the features shown on the isothermal charts all point in very much the same direction.

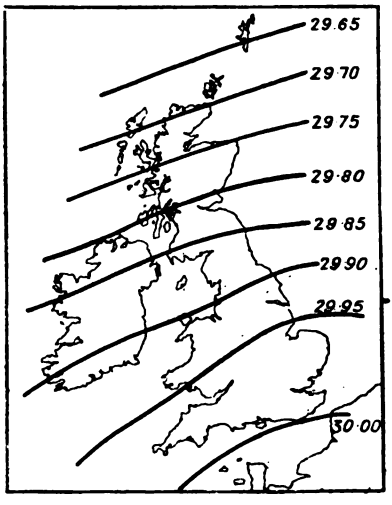


FIG. 7.—Average Barometrical Pressure, January.

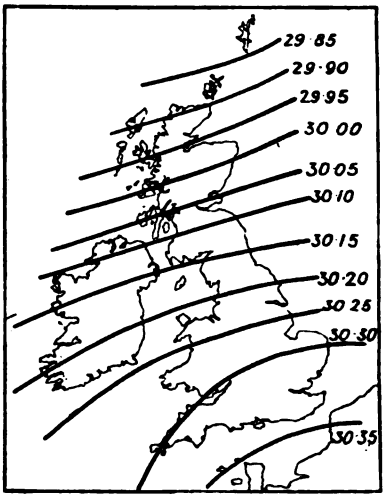


FIG. 8.—Barometrical Pressure, January 1898.

Over the western and southern portions of the United Kingdom the excess of warmth last January seems to have interfered very little with the normal distribution of temperature. In the northern, and still more in the north-eastern, districts, however, the ordinary state of things was

entirely upset, the maps in each case showing essential differences between the average and the actual conditions. Some explanation of so striking a change is undoubtedly suggested by Figs. 7 and 8, giving side by side the average distribution of barometrical pressure in January and the actual distribution recorded this year. In each map the isobars are drawn for even half-tenths of an inch, and a mere glance at the two is sufficient to show that in January 1898 the gradient for South-westerly winds was much steeper than usual. From this fact it might not unnaturally be inferred that the winds were unusually strong. This was, however, as I have already shown, far from being the case, the real fact being that, whereas in an ordinary January the normal distribution of pressure is often temporarily modified, and in some instances entirely reversed, in the month under discussion it continued unchanged throughout nearly the whole period. The mild South-westerly current of air was therefore no stronger, but far more persistent than usual; and under these circumstances it is perhaps not surprising that its chief influence should have been felt in the north-eastern parts of the United Kingdom, which enjoyed a temperature ordinarily experienced only on our south-west coasts.

From a wider survey it is, however, clear that this explanation of the undue warmth is far from complete. The synoptic charts for the whole of Europe show the prevailing conditions to have been these. Over all the more central countries a large anticyclone existed, the system often extending its borders over the eastern and southern parts of our own islands. The general effect of this high-pressure area was seen in the warding off of the large Atlantic cyclones which so often visit us in January, the centres of the main disturbances pursuing a more northerly track than usual, and passing most frequently over the northern parts of Scandinavia and Russia. In many instances their secondary areas skirted our own north-western and northern coasts, so that in those regions the weather was, as we have already seen, of a more normal character than in any other part of the country, the rainfall at some stations in the north and west of Scotland being actually in excess of the average.

With the conditions prevalent over Europe, the predominance of mild South-westerly winds over our islands and the neighbouring countries is easily explained. Over the central parts of the Continent, however, where the influence of the anticyclone was felt almost continuously, the weather should, according to all accepted rules, have been cold, if not more than ordinarily severe. That such was not the case is shown very conclusively by Table II., giving for some of the

TABLE II.—MEAN TEMPERATURE 1898, AND DIFFERENCE FROM THE AVERAGE.

Stations.	Mean Morning Temp.	Difference from Average.	Stations.	Mean Morning Temp.	Difference from Average.
	°	°		°	°
St. Petersburg .	26·2	+12·4	Prague . . .	32·5	+5·0
Moscow . . .	17·9	+ 7·3	Cracow . . .	30·2	+8·1
Hamburg . . .	38·4	+ 8·6	Vienna . . .	31·0	+5·5
Neufahrwasser .	35·2	+ 6·4	Paris	36·1	+3·0
Carlsruhe . . .	33·7	+ 2·4	Perpignan . .	45·4	+2·8

principal continental cities the mean morning temperature for January 1898, and the difference from the average for long periods of years. The average values employed were those published some few years ago by Professor Wild of St. Petersburg and issued as a supplement to the Russian *Daily Weather Report.*

The very large excess of heat at some of the more northern stations, such as St. Petersburg and Moscow, and even farther south in Germany, may doubtless be attributed to the same general cause as the warmth in our own islands. In all the more northern countries there was a strong current of wind from the westward or south-westward, and as far north as St. Petersburg severe frost was almost entirely wanting. Farther south, however, the conditions were purely anticyclonic, and yet at such stations as Prague and Vienna, and even at Perpignan, the mean temperature was considerably in excess of the average. The case undoubtedly affords striking evidence on two very important points. First, that an anticyclone in winter-time is not always accompanied by temperatures below the average; and, secondly, that in some seasons the effect of pressure distribution is entirely annulled by influences which can only be vaguely described by some such general phrases as weather "tendencies" or "propensities." These may exist either in the direction of heat or cold, of drought or rain, but when strongly marked, as in the case under review, all ordinary rules applying to the influence of cyclones or anticyclones appear to be greatly modified, if not entirely suspended. The mystery surrounding the origin and causes of such proclivities seems at present quite unfathomable, and until some light has been thrown upon the subject it is quite hopeless to look for any substantial advance in the direction of seasonal weather forecasts.

DISCUSSION.

The President (Mr. F. C. BAYARD), after thanking Mr. Brodie for his paper, said they had all remarked the phenomenally mild January and also February and March. The unseasonable weather seemed to have had a deleterious effect on the general health of the community.

Mr. B. LATHAM thought one of the most remarkable points in the month was that the high temperature was accompanied by so small an amount of rain, which was in direct contrast to what one would be led to expect, high temperature in winter and low in summer being generally held to be the conditions favourable to rainfall.

Mr. W. H. DINES said that he quite agreed with the concluding remark of Mr. Brodie as to there being some influence, at present unknown, which had great effect upon the various meteorological elements. He believed that the rule referred to as to the occurrence of cold with anticyclonic conditions existed in the imagination only and not in fact. The past winter was by no means the first that had shown the failure of the rule, and any one who would take the trouble to look up the figures might see for themselves that most of the exceptionally long or severe frosts of the present century had occurred with a comparatively low barometer, that is to say, nearly all with a pressure at Greenwich below 30·0 in. and many with one below 29·8 in. He had examined too the monthly means of temperature and barometric pressure in the winter at several Continental stations, and could not find the slightest trace of

nterdependence between them, both warm and cold winters occurring with bsolute impartiality during periods of high and periods of low barometer.

Mr. R. C. MOSSMAN said the remarkable nature of the month of January in Edinburgh might be gathered from the fact that the mean temperature was 4°·6, which was only 0°·2 below the April mean. Indeed, 56 of the last 134 Aprils had a lower mean temperature. There was no frost recorded in the month, January 1882 with 4 frosty days being the nearest approach to this during the last century. The absence of snow was not so remarkable, there having been 9 snowless Januaries since 1770.

Mr. G. J. SYMONS congratulated the Society on always having a volunteer both ready and willing to take up the discussion of any exceptional occurrence that was experienced in the country, no matter what the nature of the phenomena was, whether great gale, snowstorm, or, in fact, anything of an unusual character, so that not only had they the statistics in the *Meteorological Record*, but if any particular details were wanted of any remarkable meteorological phenomenon during the last quarter of a century, an account would generally be found in the Society's *Quarterly Journal*.

Mr. J. HOPKINSON remarked on the small mean daily range of temperature in the month, due to the nights having a greater excess of temperature than the days. At St. Albans, where he resided, the mean daily range was 8°·5 as against a mean for the 10 years 1887-96 of 10°·3. The very cloudy or gloomy nature of the month was also remarkable, the estimated amount of cloud at 9 a.m. being 9·5 against an average of 7·6. Overcast days were 7 more than the average, 25 against 18; and there was no day of clear sky, the average number for January being 3.

Mr. H. N. DICKSON inquired if Mr. Brodie had noticed any particular conditions that could in any way be regarded as having led up to this abnormal state of things. He thought a satisfactory explanation could only be gained by tracing it to its origin. Surface water was supposed to exercise some control over the distribution of pressure areas.

Mr. R. BENTLEY gave an instance of the mildness of the past January, having seen lawns mown in the valley of the Thames, showing that the growth of the grass at so unusual a period of the year had not been checked. The year 1857 appeared to have been another remarkable year, for he had noticed a record of many quarts of ripe raspberries being gathered out of doors in the neighbourhood of London at the very end of December. Going back also for 150 years he found Horace Walpole writing from Twickenham after the Christmas of 1748:—

"The weather is excessively stormy, but has been so warm and so entirely free from frosts the whole winter, that not only several of my honeysuckles are come out, but I have literally a blossom upon a nectarine tree, which I believe was never seen in this climate before at this date,"

the nectarine being a tree very susceptible to cold.

Mr. W. MARRIOTT said a glance at the isothermal lines for January 1895, when temperature was generally below the average to about the same degree that January 1898 was above it, showed them to be very similar. The two Januaries, though widely different in character, had many points in common, this agreement in variation of temperature being especially noticeable.

Mr. J. HOPKINSON remarked, with regard to the effect of the mild weather upon health, that he did not think it would be felt in the same way as a severe winter, which carries off many aged and delicate persons, while an abnormally mild winter causes a general debility more greatly felt by the robust, and therefore not materially affecting the death-rate.

Mr. F. J. BRODIE, in reply, said that he was half in sympathy with Mr. Dines' remarks as to the absence of any very intimate relation between winter

anticyclones and cold weather, and thought that in this respect the statements in some of the text-books might be judiciously modified. In answer to Mr. Dickson, he might say that he had not been able to devote much study to the conditions leading up to the abnormal weather of January, but a close daily intercourse with the charts for the whole of Europe had certainly failed to suggest any adequate explanation. There could be no doubt, as he had already said in the paper, that at certain times the weather showed distinct tendencies in the direction of cold or warmth, of rain or drought, and when these prevailed strongly they seemed to override all ordinary rules attaching to the influence of pressure distribution. A notable instance of this occurred in the spring of 1893, when the tendency for drought was so strongly marked that the advance over our island of definite cyclonic areas failed in many cases to produce any appreciable falls of rain.

ON THE FREQUENCY OF NON-INSTRUMENTAL METEOROLOGICAL PHENOMENA IN LONDON WITH DIFFERENT WINDS FROM 1763-1897.

By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

[Read June 15, 1898.]

In previous papers communicated to the Society on the non-instrumental meteorology of London, the secular and seasonal variation of some phenomena have been discussed. In the present paper the results of an analysis of the direction of the surface winds observed during the occurrence of such atmospheric visitations as snow, hail, gales, etc., will be considered. In a number of cases the direction of the wind was not noted when the phenomenon was in progress. When such was the case the general direction of the wind during the day was entered as giving a fair approximation to the true direction.

The period under discussion is the 135 years 1763-1897, and the sources from which the data were obtained have been fully described in my first paper on "The Non-Instrumental Phenomena of London."[1] The discussion of fog statistics has been confined to the eighty-seven years 1811-97, during which time the observing station was Greenwich.

Tables I.-VIII. show for the months and the year the number of times snow, hail, gales, thunderstorms, lightning without thunder, fog, dense fog, and auroras, occurred with different winds. These tables, although necessary as an essential preliminary, are of comparatively little use without a table showing the mean frequency of the winds, it being quite evident that the occurrence of, say, a gale from the South-west will depend, other causes being equal, on the frequency with which the wind in question prevails. Tables IX.-XII. were accordingly prepared to meet this difficulty. They give values which I think are fairly representative of the normal air circulation over the metropolitan area. Table IX. shows the mean number of hours the wind blew at Greenwich from different directions during the fifty years 1841-90. The labour of preparing this table was much lightened by the work done by Mr. Glaisher, who reduced the observations from

[1] *Quarterly Journal Roy. Met. Soc.* vol. xxiii. p. 288.

1841-60 and 1861-70.[1] The monthly values of wind direction for the years 1871-90 were extracted from the annual volumes of *Greenwich Magnetical and Meteorological Observations*, and the whole combined so as to show means for the fifty years under consideration. Table X., showing the mean number of days with different winds, was then prepared from Table IX., while the values given in Table XII. were obtained by multiplying those given in Table X. by 135, the number of years under consideration. Thus in January the mean number of days with a North wind was 2·5, which, multiplied by 135, gave 337 as the number of days in January with a North wind during the period 1763-1897, always assuming that the values for the fifty years 1841-90 approximate to what would have prevailed over the long period. In nearly every case seasonal and not monthly percentages are given, but monthly values can be readily computed from the detailed data given in the tables. In no instance is the mean annual percentage frequency the arithmetical mean of the monthly or seasonal values. The annual means have been obtained from the gross totals given in the tables of non-instrumental phenomena and wind direction (Table XII.)

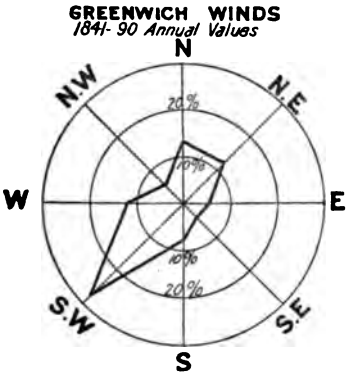


FIG. 1.

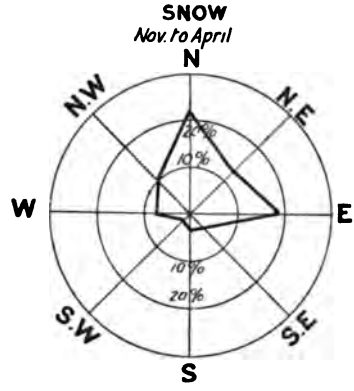


FIG. 2.

I do not intend in this paper to do more than draw attention to a few of the more general results of the inquiry, which I trust may be of some little use to those engaged in the preparation of weather forecasts for the metropolitan districts.

Snow.

The following table gives the results for snow during the six months ending with April. In October and May occurrences of this phenomenon are infrequent, so that they have been omitted. It is evident that the frequency of snow will largely depend on the temperature of the wind, indeed the tabular results give a rough approximation to the thermal wind-rose for the period of the year discussed. It will be seen that snow is of most frequent occurrence with winds from the North and East, and least common with winds from the South-west. A point of interest is the large number of snow-storms from the East in February,

[1] *Roy. Met. Soc. Proc.* i. 21, and *Quart. Journ.* i. 1.

31·1 per cent being from the East and 31·5 per cent from the North. In every other month there is a decided excess of snowy days with a North wind.

PERCENTAGE FREQUENCY OF SNOW WITH DIFFERENT WINDS.

Seasons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	CALM.
January .	42·1	25·2	26·2	5·9	6·5	1·9	10·3	20·6	3·3
February .	31·5	17·8	31·1	7·4	5·9	2·1	7·6	15·7	1·8
March .	26·2	16·3	19·8	6·6	3·7	2·0	9·0	6·5	1·3
April . .	8·4	5·5	3·7	0·7	2·5	1·1	3·8	7·4	0·0
November .	7·8	2·9	5·3	1·0	0·9	0·4	2·8	3·3	1·2
December .	27·4	16·0	25·8	1·9	3·2	1·4	6·2	10·5	0·3
Six months .	22·8	13·1	19·0	3·9	4·0	1·5	6·9	10·1	1·4

Hail.

Instead of calculating the seasonal distribution of cases of this phenomenon, I have divided hail showers into three groups. 1st. The spring maximum, which embraces the four months, February to May; this is almost entirely made up of cases of *graupel* or soft hail. 2nd. Falls of true hail, generally associated with thunderstorms, from June to September. 3rd. Ill-defined falls, principally *graupel*, from October to

FIG. 3.

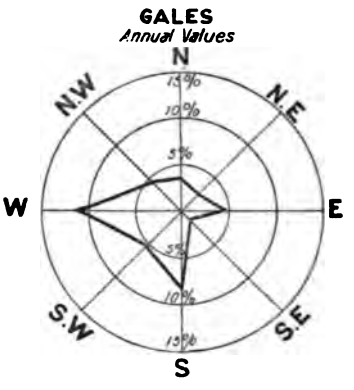


FIG. 4.

January inclusive. The last two groups, being deduced from but few observations, cannot be looked on as more than tolerable approximations, but the spring maximum shows a decided excess of hail showers with West, North-west, and North winds, which usually blow in the rear of a cyclonic disturbance, the least number being recorded with South-east winds. There is a secondary maximum in summer, with winds from the South, doubtless due to thunderstorms. The results are shown in the following table :—

PERCENTAGE FREQUENCY OF HAIL WITH DIFFERENT WINDS.

Seasons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	CALM.
Feb.-May .	5·3	2·2	2·1	1·0	3·4	2·2	9·2	7·4	0·5
June-Sept. .	0·7	0·0	0·7	0·1	1·0	0·6	1·6	0·2	0·1
Oct.-Jan. .	1·0	0·4	0·4	0·5	1·1	0·5	2·3	1·4	0·0
Year . .	2·5	1·1	1·2	0·5	1·7	1·0	4·0	3·0	0·2

Gales.

In Table XIII. I have calculated the percentage frequency of gales for each month in the year, but seasonal values are given herewith.

GALES.

Seasons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Spring .	3·7	2·6	5·5	0·5	10·3	6·5	16·7	5·7
Summer .	1·6	1·4	2·1	0·8	4·3	3·1	6·9	2·9
Autumn .	2·0	0·4	3·4	1·2	7·5	3·7	9·8	3·4
Winter .	5·0	2·8	7·4	2·0	10·9	8·1	15·9	6·3
Year .	3·0	1·8	4·6	1·2	8·5	5·3	12·1	4·6

The months were grouped according to season as follows :—February to April, spring; May to July, summer; August to October, autumn; and November to January, winter.

It will be seen from the above figures that gales are most frequent with winds from the West and South, while but few are recorded with winds from the North-east and South-east.

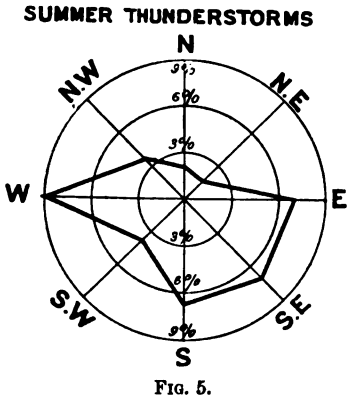


FIG. 5.

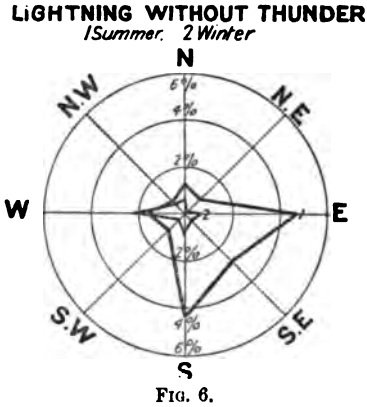


FIG. 6.

Thunderstorms.

A glance at Table IV. will show that thunderstorm phenomena naturally fall into two groups, viz. summer storms, associated with heat and small cyclonic storms; and winter storms, occurring during deep depressions. The heat thunderstorms may be said to extend from April to October, and the winter occurrences of this phenomenon from November to March. The following are the percentages :—

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Summer .	2·4	1·9	7·6	7·7	7·7	3·7	9·1	4·1	3·1
Winter .	0·0	0·0	0·0	0·2	0·6	0·4	1·3	0·6	0·0

The greatest number of both summer and winter storms occurs with winds from the West, although the values in summer are high with East, South-east, and South winds. Out of 82 winter thunderstorms only 4 were observed with polar winds.

Lightning without Thunder.

The values of this phenomenon have been referred to the same periods of the year as those of thunderstorms. The results are given in the following figures :—

Seasons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Summer . .	1·2	0·6	4·9	3·1	4·5	0·9	1·8	0·6	1·1
Winter . .	0·1	0·0	0·4	0·1	1·1	0·6	2·1	0·3	0·1

The summer maximum is thus associated with winds from the East, South-east, and South, and the winter with winds from the West, the minimum being with winds from the North-east during both periods.

Fog and Mist.

The discussion of fog and mist has been confined to the Greenwich observations made during the last eighty-seven years. A table similar to Table XII. was prepared and the seasonal results calculated.

The following are the seasonal percentages :—

Season.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Feb.-April .	10·0	4·5	19·7	4·1	5·6	3·1	10·9	5·4	23·8
May-July .	3·4	1·8	5·6	1·7	0·8	0·8	3·4	1·2	5·6
Aug.-Oct. .	13·8	10·4	33·1	10·0	8·5	3·3	11·8	6·1	22·5
Nov.-Jan. .	22·6	8·5	38·7	11·5	10·2	6·6	26·8	11·9	35·1
Mean . .	16·8	5·8	22·9	7·2	6·7	3·5	13·2	6·1	23·0

General Mean, 9·2.

It will be seen that the greatest number of fogs are recorded on calm days closely followed by days on which the wind blew from the East. The great increase of fog during autumn and winter is well seen, the rise from summer to autumn being very decided.

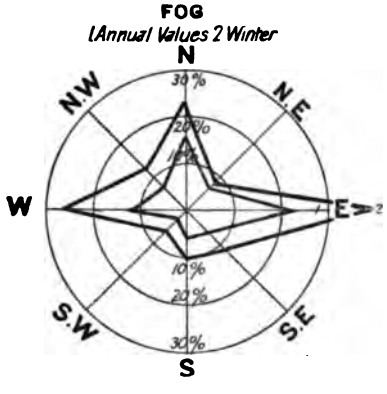


FIG. 7.

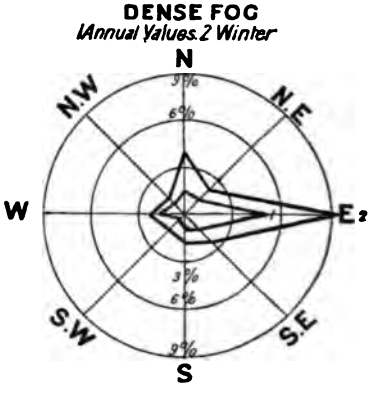


FIG. 8.

Dense Fog.

The following figures showing the frequency of dense fog may be of interest. Here again the greatest number occurs with Easterly airs or with calms :—

Seasons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Feb.-April . .	0·6	0·7	4·2	1·0	0·9	0·4	0·9	0·7	4·6
May-July . .	0·4	0·3	0·5	0·0	0·0	0·1	0·2	0·0	1·3
Aug.-Oct. . .	1·3	2·5	7·0	2·6	1·5	0·5	1·1	0·2	7·1
Nov.-Jan. . .	3·7	2·1	9·7	2·6	1·8	1·4	2·0	1·3	14·7
Mean . . .	1·4	1·2	5·0	1·6	1·1	0·6	1·5	0·6	5·5

General Mean, 1·7 per cent.

In the following table I have analysed the frequency with which fog is reported "dense" or "thick" with various winds. This table is based on Tables VI. and VII. Thus, for example, the total number of fogs occurring with a North wind during the period under review was 410, of which 48 were dense (see Table VII.), or 11·7 per cent of the whole. The chances of a fog being dense are of course greatest when the air is calm, but the values with North-east, East, and South-east winds are practically the same, the lowest percentage being reported with North-west winds.

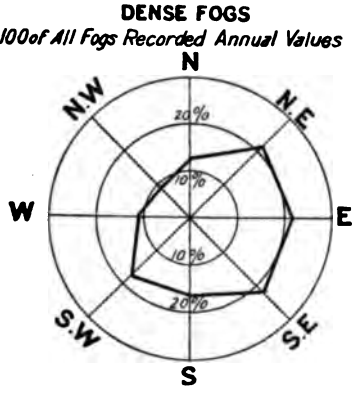


Fig. 9.

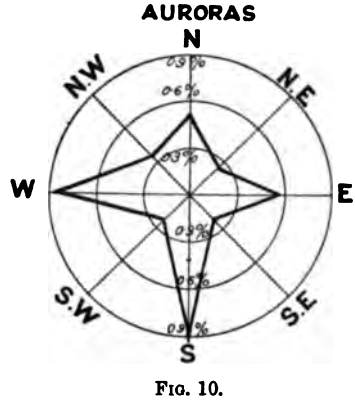


Fig. 10.

In 100 fogs recorded with different winds the following were dense or thick :—

Seasons.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Feb.-April . .	5·9	15·4	21·5	21·0	15·7	13·1	8·3	13·8	19·4
May-July . .	1·2	15·0	8·8	0·0	0·0	15·8	5·9	0·0	23·8
Aug.-Oct. . .	9·3	23·9	21·2	25·5	17·5	16·0	9·4	3·6	33·8
Nov.-Jan. . .	16·2	24·2	25·0	23·0	17·9	21·0	14·7	10·9	41·8
Mean . . .	11·7	21·3	21·8	22·9	16·9	18·0	11·6	9·3	33·0

General Mean, 19·0.

Auroras.

Table VIII. shows the number of times the wind blew from different directions during the occurrence of the Aurora Borealis. The annual percentage frequency is given in the following figures :—

N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
0·54	0·24	0·57	0·23	0·93	0·24	0·88	0·36	0·13

It is, of course, impossible to say what the above figures really mean, but the infrequency of auroræ during calm weather seems to indicate that they are indirectly connected with unsettled atmospheric conditions. This may, however, be largely due to the preponderance of auroral displays in autumn when stormy weather is not uncommon.

TABLE I.—Showing the Number of Times Snow fell with each Wind from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total.
January .	142	102	106	20	37	26	53	39	9	534
February .	123	84	88	17	24	24	35	36	4	435
March . .	138	97	75	17	12	21	46	22	3	431
April . .	42	41	19	2	8	10	15	20	0	157
May . .	9	2	0	0	1	2	1	5	0	20
September.	1	0	0	0	0	0	0	1	0	2
October .	11	1	0	0	1	0	2	3	0	18
November.	39	13	15	3	4	4	12	9	3	102
December .	107	56	66	5	14	19	37	27	1	332
Total .	612	396	369	64	101	106	201	162	20	2031

TABLE II.—Showing the Number of Times Hail fell with each Wind from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total.
January .	2	2	2	0	9	7	17	7	0	46
February .	10	7	5	2	11	16	25	14	0	90
March . .	26	21	12	1	16	31	47	22	0	176
April . .	40	24	15	5	11	24	52	27	3	201
May . .	28	6	2	2	10	19	35	13	1	116
June . .	6	1	2	1	5	15	16	0	1	47
July . .	0	0	2	0	2	8	7	0	0	19
August . .	1	0	2	0	4	4	7	0	0	18
September	5	0	1	0	2	5	7	2	0	22
October .	3	0	0	1	2	7	9	2	0	24
November.	4	1	1	2	5	1	14	2	0	30
December .	7	3	1	2	4	9	8	3	0	37
Total .	132	65	45	16	81	146	244	92	5	826

TABLE III.—Showing the Number of Times Gales occurred with each Wind from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Variable.	Total.
January .	24	14	23	8	49	109	96	17	0	340
February .	20	12	11	1	53	76	89	19	0	281
March . .	17	18	37	0	31	83	99	22	0	307
April . .	15	17	17	3	25	39	40	7	0	163
May . .	13	19	13	1	19	35	27	10	1	138
June . .	6	4	2	1	9	36	40	6	0	104
July . . .	4	2	5	3	15	43	40	6	0	118
August . .	9	2	6	3	22	30	43	4	0	119
September	6	1	9	3	31	49	39	10	0	148
October .	10	3	12	3	33	61	83	10	0	215
November.	19	11	13	6	47	88	65	12	0	260
December .	19	9	21	4	62	111	83	16	0	325
Total .	162	112	169	36	395	760	744	139	1	2518

TABLE IV.—Showing the Number of Times Thunderstorms occurred with each Wind from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total.
January .	0	0	0	0	2	2	3	4	0	11
February .	0	0	0	0	2	2	3	0	0	7
March . .	1	0	0	1	0	9	10	2	0	23
April . .	1	4	9	11	12	21	27	9	4	98
May . .	14	21	30	23	15	26	36	12	10	187
June . .	20	15	37	24	36	57	60	8	10	267
July . .	16	16	37	31	59	86	97	17	14	373
August . .	15	11	35	22	35	73	64	16	9	280
September .	8	3	18	12	22	38	38	8	4	151
October .	1	2	5	3	12	11	8	2	1	45
November .	0	0	0	1	8	5	10	2	0	26
December .	0	0	0	1	1	6	7	0	0	15
Total .	76	72	171	129	204	336	363	80	52	1483

TABLE V.—Showing the Number of Times Lightning without Thunder occurred with each Wind from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total.
January .	2	0	1	1	2	6	13	1	0	26
February .	0	1	1	0	2	3	6	0	0	13
March . .	0	0	0	1	3	5	3	0	1	13
April . .	3	0	11	7	8	4	3	0	0	36
May . .	4	3	13	6	13	8	8	0	2	57
June . .	1	3	21	7	14	10	2	0	3	61
July . .	5	4	22	6	14	11	13	0	5	80
August . .	13	8	22	7	21	17	8	5	8	109
September	5	3	16	10	23	14	12	4	0	87
October .	6	4	5	8	19	17	26	1	0	86
November .	0	0	2	0	11	12	15	0	0	40
December .	0	0	2	0	6	12	15	2	0	37
Total .	39	26	116	53	136	119	124	13	19	645

TABLE VI.—Showing the Number of Times Fog occurred with each Wind from 1811-97.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Total.
January .	36	26	66	23	25	46	74	11	46	353
February .	35	18	53	9	19	28	44	13	43	262
March . .	39	19	59	7	13	23	37	8	33	238
April . .	17	15	37	4	6	10	15	8	17	129
May . .	13	7	15	2	2	1	13	3	7	63
June . .	12	8	13	5	2	4	11	3	9	67
July . .	7	5	6	0	1	14	10	0	5	48
August . .	9	15	31	2	6	6	17	9	12	107
September	34	32	74	19	17	25	31	8	50	290
October .	65	45	65	26	40	50	80	11	75	457
November .	75	24	61	23	40	55	91	24	73	466
December .	68	16	65	20	30	61	101	20	70	451
Total .	410	230	545	140	201	323	524	118	440	2931

TABLE VII.—Showing the Number of Times Dense Fog occurred with ea Wind from 1811-97.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Tota
January .	5	3	13	4	4	16	7	1	19	72
February .	3	4	15	2	4	6	4	2	11	51
March . .	0	3	15	1	2	1	4	1	5	32
April . .	2	1	2	2	0	1	0	1	2	11
May . .	1	2	2	0	0	0	1	0	2	8
June . .	2	1	1	0	0	1	0	0	2	7
July . .	1	0	0	0	0	2	1	0	1	5
August . .	1	1	5	1	2	2	3	1	3	19
September.	2	11	15	3	3	0	5	0	11	50
October .	7	10	16	8	6	11	4	0	29	91
November.	13	6	16	9	11	8	19	3	31	116
December .	11	7	19	2	2	10	13	2	29	95
Total .	48	49	119	32	34	58	61	11	145	557

TABLE VIII.—Showing the Number of Times Auroras were recorded wi each Wind from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Tota
January .	1	0	0	0	5	2	7	0	0	15
February .	4	2	1	0	5	5	8	6	0	31
March . .	2	0	1	1	2	3	3	1	0	13
April . .	6	2	4	0	5	2	3	0	0	22
May . .	2	2	2	1	0	1	1	1	0	10
June . .	0	0	1	0	0	0	0	0	0	1
July. . .	0	0	2	0	1	0	2	0	0	5
August . .	3	1	1	2	3	5	1	0	2	18
September.	2	3	6	1	7	6	7	1	1	34
October .	4	1	2	2	10	5	8	2	1	35
November.	2	2	1	0	5	4	7	0	0	21
December .	3	2	0	0	0	2	7	0	0	14
Total .	29	15	21	7	43	35	54	11	4	219

TABLE IX.—Direction of the Wind at Greenwich from 1841-90, deduci from Hourly Observations. Mean Number of Hours the Direction was–

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January .	60·6	72·8	40·6	58·8	100·0	238·6	91·0	34·3	47·3
February .	71·0	85·1	50·0	40·5	71·4	198·3	81·5	40·5	39·4
March .	93·7	106·7	68·5	45·1	57·3	182·9	91·0	59·0	39·8
April . .	88·4	132·7	91·8	46·9	58·2	156·1	70·4	46·9	28·6
May . .	97·3	147·9	77·1	42·8	60·9	183·5	65·8	33·5	35·2
June . .	88·2	90·0	56·2	40·0	55·9	219·6	94·6	46·6	28·9
July. . .	74·0	72·8	36·3	27·7	63·5	264·0	115·1	51·7	38·9
August . .	68·4	68·7	43·3	34·9	62·6	256·8	110·6	47·6	51·1
September	71·0	100·2	47·4	43·8	61·1	212·1	89·6	34·3	60·5
October .	73·4	73·4	50·2	54·0	79·8	212·4	98·5	45·3	57·0
November.	89·1	78·3	50·4	50·5	80·3	201·1	78·0	47·8	44·6
December .	69·9	61·4	44·5	48·0	77·2	235·2	106·4	45·6	55·8
Total .	945·0	1090·0	656·3	533·0	828·2	2560·6	1092·5	533·1	527·1

TABLE X.—Direction of the Wind at Greenwich, 1841-90. Mean Number of Days it blew from the following Directions:—

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January .	2·5	3·0	1·7	2·5	4·2	9·9	3·8	1·4	2·0
February .	2·9	3·5	2·1	1·7	3·0	8·3	3·4	1·7	1·6
March . .	3·9	4·4	2·8	1·9	2·4	7·6	3·8	2·5	1·7
April . .	3·7	5·5	3·8	2·0	2·4	6·5	2·9	2·0	1·2
May . .	4·1	6·2	3·2	1·8	2·5	7·6	2·7	1·4	1·5
June . .	3·7	3·7	2·3	1·7	2·3	9·1	4·0	2·0	1·2
July. . .	3·1	3·0	1·5	1·2	2·6	11·0	4·8	2·2	1·6
August . .	2·9	2·9	1·8	1·4	2·6	10·7	4·6	2·0	2·1
September	3·0	4·2	2·0	1·8	2·6	8·7	3·8	1·4	2·5
October .	3·1	3·1	2·1	2·2	3·3	8·8	4·1	1·9	2·4
November.	3·7	3·3	2·1	2·1	3·3	8·4	3·2	2·0	1·9
December .	2·9	2·6	1·9	2·0	3·2	9·8	4·4	1·9	2·3
Total .	39·5	45·4	27·3	22·3	34·4	106·4	45·5	22·4	22·0

TABLE XI.—Direction of the Wind at Greenwich, 1841-90. Mean Percentage Frequency.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January .	8·1	9·8	5·5	7·9	13·4	32·1	12·2	4·6	6·4
February .	10·5	12·5	7·4	6·0	10·5	29·3	12·0	6·0	5·8
March . .	12·6	14·3	9·2	6·1	7·7	24·6	12·2	7·9	5·4
April . .	12·3	18·4	12·7	6·5	8·1	21·7	9·8	6·5	4·0
May . .	13·1	19·9	10·4	5·7	8·2	24·7	8·8	4·5	4·7
June . .	12·2	12·5	7·8	5·6	7·8	30·5	13·1	6·5	4·0
July . .	9·9	9·8	4·9	3·7	8·5	35·5	15·5	7·0	5·2
August . .	9·2	9·2	5·8	4·7	8·4	34·5	14·9	6·4	6·9
September	9·9	13·8	6·6	6·1	8·5	29·5	12·4	4·8	8·4
October .	9·9	9·9	6·7	7·3	10·7	28·5	13·2	6·1	7·7
November.	12·4	10·9	·7·0	7·0	11·1	27·9	10·8	6·6	6·3
December .	9·4	8·2	6·0	6·5	10·4	31·6	14·3	6·1	7·5
Year .	10·8	12·4	7·5	6·1	9·4	29·2	12·5	6·1	6·0

TABLE XII.—Showing the Number of Days of each Wind in London from 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January .	337	405	229	337	567	1336	513	189	270
February .	391	472	283	229	405	1120	459	230	216
March . .	526	594	378	256	324	1026	513	337	230
April . .	499	742	513	270	324	877	391	270	162
May . .	553	837	432	243	337	1026	364	189	202
June . .	499	499	310	229	310	1228	540	270	162
July. . .	418	405	202	162	351	1485	648	297	216
August . .	391	391	243	189	351	1444	621	270	283
September.	405	567	270	243	351	1174	513	189	337
October .	418	418	283	297	445	1188	553	256	324
November.	499	445	283	283	445	1134	432	270	256
December .	391	351	256	270	432	1323	594	256	310
Total .	5327	6126	3682	3008	4642	14,361	6141	3023	2968

TABLE XIII.—Percentage Frequency of Gales with Different Winds, 1763-1897.

Months.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January .	7·1	3·5	10·0	2·4	8·6	8·2	18·7	9·0	
February .	5·1	2·5	3·9	0·4	13·1	6·8	19·4	8·3	
March . .	3·2	3·0	9·8	0·0	9·7	8·0	19·3	6·5	
April . .	3·0	2·3	3·3	0·6	7·7	4·5	10·2	2·6	
May . .	2·4	2·3	3·0	0·4	5·7	3·9	7·4	5·3	
June . .	1·2	0·8	0·6	0·4	2·9	2·9	7·4	2·2	
July . . .	1·0	0·5	2·5	1·9	4·3	2·9	6·2	2·0	
August . .	2·3	0·5	2·5	1·6	6·3	2·1	6·9	1·5	
September.	1·5	0·2	3·3	1·2	8·8	4·2	7·6	1·3	
October .	2·4	0·7	4·2	1·0	7·4	5·1	15·0	3·9	
November .	3·8	2·5	4·6	2·1	10·3	7·8	15·0	4·4	
December .	4·9	2·6	8·2	1·5	14·4	8·4	14·0	6·2	
Total .	3·04	1·83	4·59	1·20	8·51	5·29	12·11	4·58	

General Mean, 5·11.

DISCUSSION.

The President (Mr. F. C. Bayard) said they were much indebted to Mr. Mossman for his paper, which formed a good supplement to previous papers by him on the Non-Instrumental Meteorology of London. He did not think that snow was of such rare occurrence after April as Mr. Mossman's figures showed. On May 18 of this year a slight fall of snow took place at Warlingham in the early morning.

Mr. R. H. Curtis said that the object of this paper, as set out in the title, was to connect the occurrence of certain phenomena with the direction of wind at the time of its occurrence, and also with the relative frequency of winds from all points of the compass. As regards the latter part of the inquiry it was of course important, if the inquiry was to have any value, that the data employed should be reliable; but from Mr. Mossman's account of the way in which it had been obtained he thought this was hardly the case, and to his mind it appeared to be a very unsafe way of dealing with so variable an element as wind-direction to assume, as Mr. Mossman had done, that the values for 50 years represented also that for the preceding 85 years: to that extent he thought the comparison was very weak. As regards fog, we were told that the data used were not the same as for the other phenomena dealt with, and were for 87 years only, and referred to Greenwich alone. It struck him as peculiar, and it was certainly contrary to his own observation, that in dense London fogs so few as 26 per cent occurred with calms; he thought it would be more correct to say that at that time it was invariably calm. He would like to know, before attaching much value to these figures, whether the wind directions were obtained from the anemograms, and if so, how a "calm" had been distinguished? He knew that in some cases it was the practice to take the wind direction without reference to the force; in which case many of the entries were not what they purported to be, but were simply repetitions of the position of the vane when the wind last blew with sufficient force to move it. This was shown by the sudden change of direction, through many points, which frequently occurred when next the wind freshened.

Mr. F. Gaster said that if such a principle as that adopted by Mr. Mossman with regard to the observations, and to which attention had been drawn by

Mr. Curtis, were allowed by meteorologists, anything like reliable results could not be expected from those who professed to calculate values for any force. It ignored altogether the possibility of any secular change in the elements dealt with, and made it possible to "manufacture" values for long periods from short ones by a simple arithmetical process, the results of which must be disastrous. Then with regard to the hope expressed by the author that the results of the paper might be of some use to those engaged in weather forecasting for the metropolitan area, he (Mr. Gaster) failed to see in what manner the values might be used at all. It seemed to him that the results quoted had been very common knowledge for many years—*e.g.* that both fogs and gales were of greater frequency in winter than in summer, that the large majority of gales experienced blew from between South-west and West, and so on. What is wanted for forecasting is a careful discussion of actual conditions carefully grouped as to pressure distribution, the prevalence of definite wind currents, rains, etc. If all the data had been so analysed, and the changes from day to day had been carefully considered, he thought the results would have been much more valuable. As it is, however, he considered Mr. Mossman had thrown away his time. He thought too much had been made of monthly averages; for the purpose of aiding forecasting we have to deal with conditions varying from hour to hour, and in every conceivable variety, and we have if possible to discover the causes. Monthly averages completely mask such conditions, and give results which in their bare statement are most confusing.

Mr. W. Lyon said that in 1867 the Epsom Derby was run in a snowstorm, this race taking place at the end of May. Also the Oxford and Cambridge boat-race had been rowed about the end of March in a blinding snowstorm. It would be interesting to have the records of wind direction for these dates.

Mr. B. Woodd Smith did not see the object in having separate tables for thunderstorms and lightning, it being generally understood that the difference was only a matter of distance.

Mr. F. J. Brodie agreed with Mr. Gaster as to the great lack of originality in the conclusions set forth in the paper. He also took exception to the novel method by which the year had been divided seasonally, and according to which February ranked as a spring, and August as an autumn month. The question was, he admitted, a contentious one, all attempts to lay down correct seasonal limits being greatly hampered by the common and long-established practice of computing weather results for calendar months. To get an ideal division of the year it seemed necessary to break up the months, and to assign a larger period to the summer and winter, than to the spring and autumn seasons. Under such an arrangement the spring would include the two months from the middle of March to the middle of May; the summer the four months beginning with the middle of May and running till the middle of September; the autumn the two months from the middle of September to the middle of November; and the winter the four months running from the middle of November until the middle of March.

Mr. R. C. Mossman (in a note to the Secretary in reply) said that the wind observations were not obtained from anemograms until the commencement of the Greenwich record in 1840. He could not say how the different observers had distinguished a calm. Although agreeing with his critics that the paper had some weak points, he did not think that the time expended in its compilation had been altogether thrown away. The statistical analysis of the relation of wind direction to non-instrumental phenomena would probably be of use, as would be the fifty years' means of Greenwich wind direction.

THE EXPLORATION OF THE FREE AIR, BY MEANS OF KITES, AT BLUE HILL OBSERVATORY, MASS., U.S.A.

By A. LAWRENCE ROTCH, S.B., A.M., F.R.Met.Soc., Director.

[Read June 15, 1898.]

The first use of kites for scientific purposes, so far as is known, was in 1749, when Dr. Alexander Wilson and his pupil Thomas Melville of Glasgow raised thermometers attached to kites into the clouds.[1] Three years later Benjamin Franklin performed in Philadelphia his celebrated experiment of collecting the electricity of the thunderstorm by means of a kite.[2] During the first part of the present century kites were used in Europe to carry thermometers into the air, and about 1840 Espy employed kites in the United States to verify calculations of the height of clouds by means of the dew-point.[3]

Modern Scientific Kite-flying.

Modern kite-flying for scientific purposes may be said to date from 1883, when Douglas Archibald, in England, fastened to the kite-wire anemometers which registered the total wind movements on dials, and so obtained differential measures of wind velocity at heights up to 1200 feet.[4] In 1885 Alexander McAdie (now of the United States Weather Bureau) repeated Franklin's experiments on Blue Hill, using an electrometer,[5] and in 1891 and 1892 he measured simultaneously the electric potential at the base of Blue Hill, on the hill, and with kites as collectors, at several hundred feet above the hill-top. About the same time L. Weber in Breslau, Germany, made a more extended use of kites to collect atmospheric electricity.[6]

History of the Work at Blue Hill.

To William A. Eddy of Bayonne, New Jersey, is due the credit of again turning the attention of scientific men to kite-flying, and thus causing the widespread interest in it which now exists. About 1890 Mr. Eddy used an ordinary kite to lift thermometers, but soon afterwards devised a tailless kite, which resembled the kite used in Java. This kite has the ends of its horizontal cross-stick bent backwards, and the convex surface exposed to the wind obviates the necessity of a tail and enables the kite to be easily flown. In 1891 Mr. Eddy attached a minimum thermometer to several of these tailless kites flown tandem, and proposed to obtain in this way data for forecasting the weather.[7] In the Proceedings of the Aeronautical Conference held in connection with the Chicago Exposition of 1893, Prof. M. W. Harrington, then Chief of the United States Weather Bureau, quoted Mr. Eddy's estimate

[1] *Trans. Roy. Soc. Edin.*, vol. x. part ii. pp. 284-286.
[2] Sparks's *Works of Franklin*, vol. v. p. 295.
[3] Espy's *Philosophy of Storms*, p. 75.
[4] *Nature*, vol. xxxi.
[5] *Proc. American Acad. Arts and Sci.*, vol. xxi. pp. 129-134.
[6] *Electrotechnische Zeitschrift*, Nov. 1886, Aug. 1889.
[7] *American Met. Journal*, vol. viii. pp. 122-125.

of the cost of exploring the air to a height of 15,000 feet by means of kites flown in series.

Up to this time it does not appear that self-recording instruments—that is to say, those which yield continuous graphic records—had been raised by kites. In the days of the early experimenters such instru-

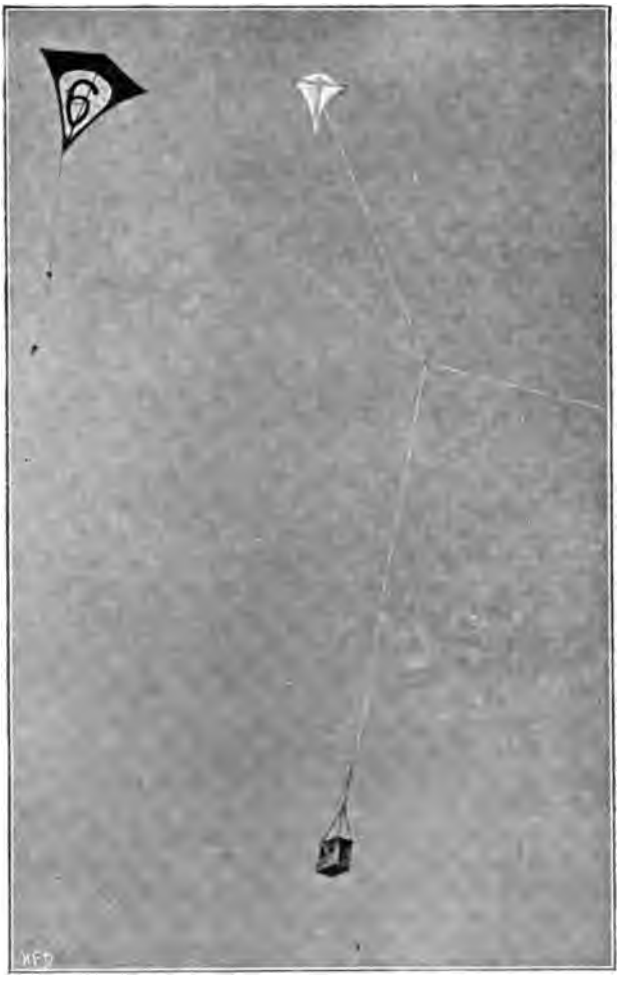


FIG. 1.—Meteorograph lifted by Eddy Kites, May 4, 1897.

ments were too heavy to be lifted by kites, as these latter would be more or less unmanageable. Within the past few years the self-recording instruments made in Paris by M. Richard are both light and simple, so that it became possible to obtain simultaneous records at the kite and at a station on the ground, and from these to study the changes of temperature and humidity. This seems to have been done first at Blue Hill Observatory by my assistants, Messrs. Clayton and Fergusson. In

August 1894, Mr. Eddy brought his kites to Blue Hill, and with them lifted a Richard thermograph, which had been partly reconstructed of aluminium by Mr. Fergusson, so that it weighed but 2¼ lbs., to the height of 1500 feet, where the earliest automatic record of temperature was obtained by a kite.[1] During the next summer Mr. Eddy assisted again in the experiments at Blue Hill, and secured photographs from a camera carried between his kites. Now that the possibility of lifting self-recording meteorological instruments to considerable heights had been demonstrated, an investigation of the thermal and hygrometric conditions of the free air was undertaken by the staff of the Blue Hill Observatory, who had already made a detailed study of the movements of the air at great heights, from the observations of clouds.[2]

The development of the kite and its accessory apparatus, and the acquisition of the knowledge how to use them, required much time and resulted in the damage or loss of many kites. Two costly "meteorographs," as the combination of self-recording instruments is called, were dropped from a great height, and no trace of them could be found. Usually, however, when, by the breaking of the line, kites and instruments were carried away, they fell gently to the ground and were recovered uninjured. It would be tedious to recount the vicissitudes of kite-flying at Blue Hill which have resulted in the present system of work, so only a brief historical statement will be given, to be followed by a description of the methods now in use.

At first the Eddy, or Malay kite, as it is sometimes called, was employed. Several of these kites, which were covered first with paper and later with varnished cloth, were coupled tandem to secure greater safety and more lifting power. The first meteorograph, being a combined recording thermometer and barometer, was constructed by Mr. Fergusson, who, in November 1895, united an anemometer with the thermometer. Two meteorographs were made by J. Richard, of Paris, which recorded three elements, viz. atmospheric pressure (from which the height of the instrument can be calculated), air temperature, and relative humidity. The first of these meteorographs was ordered in 1895 on the model of one carried by French aeronauts, but since, for use with kites, lightness is all-essential, M. Richard constructed his triple recorder for the first time of aluminium, and thereby reduced its weight to 2¼ lbs.[3] One of these meteorographs was hung to a ring at the point of attachment of the two kite-lines to the main line, a method which was used until recently. In August 1895, in conjunction with the Eddy kites, there was first used the cellular or box kite, invented by Lawrence Hargrave of Sydney, New South Wales, which was built from a description published shortly before.[4] At the present time some form of the Hargrave kite is generally employed at Blue Hill and elsewhere. Notwithstanding the efficiency of these kites, on account of the weight of the large cord necessary to control them, and the surface which this cord presented to the wind, it was found impossible to lift the meteorograph to the height of 2000 feet. During January 1896, following Archibald's example and

[1] *Scientific American*, Sep. 15, 1894.
[2] *Annals Astr. Obs. Harv. Col.*, vol. xxx. part iii.
[3] *La Nature*, Feb. 8, 1896.
[4] *Engineering*, Feb. 15, 1895.

the methods of deep-sea sounding described by Captain Sigsbee, U.S.N., steel pianoforte wire was substituted for cord, and with this wire, which although lighter and smaller had greater strength than the cord, the height of a mile was reached in July, and a mile and three-quarters in October, 1896.[1] Up to this time a reel turned by two men sufficed to draw down the kites, but with the increasing pull and length of wire, recourse to steam was necessary. In January 1897 a grant of money

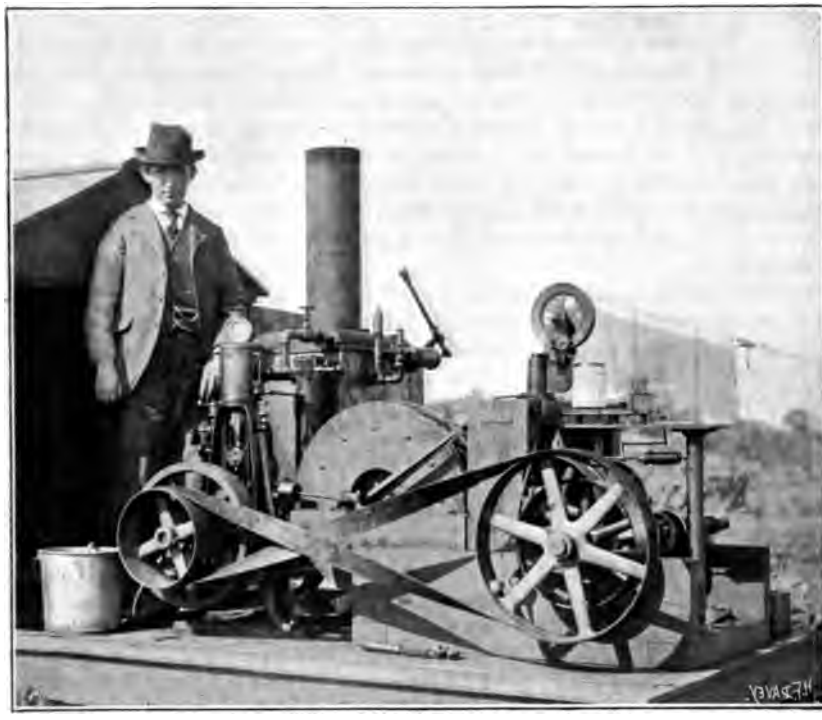


FIG. 2.—Steam Power Windlass for Kites, 1897-98.

was allotted from the "Hodgkins Fund" of the Smithsonian Institution for the purpose of obtaining meteorological records at heights exceeding 10,000 feet. With this grant a steam windlass was built by Mr. Fergusson, with ingenious devices for distributing and measuring the wire, but the cumulative pressure of the successive coils of wire finally crushed the drum. Our next apparatus was copied from the deep-sea sounding machine of Sir William Thomson (now Lord Kelvin), and with it records were brought down from the prescribed height in October 1897.

Kites and Apparatus now used at Blue Hill.

The kites and apparatus now used at Blue Hill are as follows:— The kites generally have two rectangular cells covered with nainsook cloth, except at their tops and bottoms, and one is secured above the

[1] *Monthly Weather Review* of United States Weather Bureau, Sept. 1896.

other by four or more sticks. The wooden frames are as light as possible, but are made rigid by guys of steel wire which bind them in all directions. Some of the kites stand nearly 9 feet high, have 64 square feet of lifting surface, and weigh 6 lbs. A very efficient but complex form is Lamson's aero-curve folding kite, which has the sustaining surfaces of its forward cell curved like a bird's wing, while the rear cell, with triangular superposed planes, acts as a tail or rudder. With a short line the kites fly at an angle of from 50° to 60° above the horizon, and in a wind of 20 miles an hour they exert a pull on the line, at this angle, of about 1 lb. for each square foot of lifting surface. In the bridle or hanger of the Blue Hill kites an elastic cord has been inserted, which stretches when the wind pressure increases beyond a safe amount, causing the kite to fly more nearly horizontal while the gust lasts. These kites may be started in a wind which blows more than 12 miles an hour, and they continue to fly in gales of 50 miles per hour. On Blue Hill the average velocity of the wind for the year is 18 miles an hour, consequently there are few days when kites cannot be flown there.

The flying lines are fastened into a ring at the end of the wire, where the meteorograph is sometimes hung by a cord with a spiral spring interposed to lessen the shocks. With the increased stability and strength of our new kites, it is found advantageous to suspend the meteorograph directly from the top kite. The main line is steel "music wire," capable of withstanding a pull of 300 lbs., and weighing 15 lbs. per mile. Several miles of this wire are spliced together with the greatest care, special pains being taken that no sharp bends occur which would cause it to break. To manipulate this wire the deep-sea sounding apparatus, driven by steam, has been modified by Mr. Fergusson to pull obliquely downwards. The wire from the kites passes over a swivelling pulley, which follows the direction of the wire and registers on a dial the exact length of wire unreeled. Next the wire bears against a pulley carried by a strong spiral spring, by which the pull upon the wire at all times is graphically recorded on a paper-covered drum turned by clockwork. The wire then passes several times around the strain-pulley, and finally is coiled under slight tension upon a large storage drum. When the kites are to be pulled down the strain-pulley is driven by a belt from a 2 horse-power Shipman automatic steam-engine. When they are rising the belt is disconnected and the pull of the kites is sufficient to unreel the wire. The usual rate of speed at which the wire is drawn in is from 3 to 6 miles an hour. In order to lift the increasing weight of wire it is customary to attach kites at various points on the wire, according to the pull upon it, so that nearly the same angular elevation may be maintained. This is done by screwing on the wire aluminium clamps to which the flying lines of the kites are tied or connected by toggles. The French meteorograph is enclosed in an aluminium cage of about a foot cube and weighs, complete, less than 3 lbs. The cage contains a barometer, a thermometer, and a hygrometer, which all record their readings automatically on one cylinder turned by clockwork in twelve hours. It is only necessary to screen the thermometer from the sun's rays to obtain the true air temperature, since the wind insures the circulation of air. A kite-meteorograph lately constructed by Mr.

Fergusson contains an anemometer, barometer, thermometer, and hygrometer, and yet weighs but 3 lbs.

The method of making a kite-flight for meteorological purposes at Blue Hill is as follows:—A kite, fastened by a long wire to the ring in the main wire and the suspended meteorograph, being in the air, another tube is attached to the ring by a shorter cord. The kites are then allowed to rise, and to unreel the wire, until the angle with the horizon becomes low, when, by means of the clamp just described, another kite is added, and so on. After a pause at the highest attainable altitude the reel is connected with the steam-engine, and the kites are drawn down. The pauses at the highest point, and when kites are attached or detached, are necessary to allow the recording instruments to acquire the conditions of the surrounding air; and because at these times the meteorograph is nearly stationary, measurements of its angular elevations are made with a surveyor's transit. Since the length of the wire is known, the height of the meteorograph can be calculated, it having been found that the sag of the wire, or its deviation either in a vertical or a horizontal plane from the assumed cord of the approximate arc which the wire follows, does not cause an error exceeding 3 per cent in the height so computed. When the meteorograph is hidden by clouds, the height above the last point trigonometrically determined, is computed by Laplace's formula from the barometer record. The time of making each angular measurement is noted, so that the corresponding point on the trace of the meteorograph may be found. Before and after the flight the meteorograph is hung upon a tripod in the free air, in order that its thermometer and hygrometer may be compared with those in the louvred screen.

Noteworthy Flights.

Since the use of wire and more efficient kites, the heights have been greatly increased. Thus the average height above the hill attained by the meteorograph in the seven flights made during May was nearly a mile and a half, whereas the average height of all the ascents prior to 1896 was only about a quarter of a mile.

The greatest height ever reached by a kite was above Blue Hill on October 15, 1897, when the meteorograph was lifted 11,080 feet vertically above Blue Hill, or 11,710 feet above the neighbouring ocean. At the end of the line were Lamson's aero-curve kite and a Hargrave kite, while two other Hargrave kites were attached respectively at distances of 6500 feet and 11,500 feet from the end, their combined lifting surface being 150 square feet. The 20,100 feet of wire in the air weighed 60 lbs., and transmitted to the reel a maximum pull of 150 lbs. During the flight, which occupied but four and a half hours, the velocity of the wind at the ground varied from 13 to 22 miles an hour. In this flight, as in a previous high flight, the temperature fell on the average about 1° for each 360 feet rise, but during the daytime this decrease was slower in the upper air, confirming Glaisher's observations in balloons. An interesting phenomenon was, that although the sky remained clear, strata of high humidity were encountered at nearly the same height in the ascent and descent, corresponding to the levels at which the cumulus

and alto-cumulus clouds usually form. At the highest point the air contained a very small percentage of moisture. Facsimiles of the traces of the instruments were given in the *U.S. Monthly Weather Review* for September 1897, in *Nature* of February 17, 1898, and in *Bulletin No.* 1 of the Blue Hill Observatory. In September 1897 the meteorograph was twice maintained at the nearly constant height of 1700 feet during the greater portion of twenty-four hours, and flights were made on seven consecutive days. These records have been discussed by Mr. Clayton in *Bulletin No.* 2 of the Blue Hill Observatory under the title "Examples of the Diurnal and Cyclonic Changes of Temperature and Relative Humidity at Different Heights in the Free Air."

General Results.

About two hundred records from kites have been obtained in the free air at heights of 100 to 11,000 feet above Blue Hill, in all kinds of weather. The records before February 1897 are discussed by Mr. Clayton in Appendix B to part i. of vol. xlii. of the *Annals of the Astronomical Observatory of Harvard College*, and some general conclusions can be stated here. As regards wind, the observations show that, as a rule, the wind steadily increases with elevation, confirming the measurements made upon clouds. The tendency of the kites as they rise is to come into a current from the west, and it is possible, with no great difference of height, to find currents almost diametrically opposed to each other. The decrease of temperature with increasing elevation varies under different conditions. On most days when there are no clouds the temperature falls at the adiabatic rate for unsaturated air, *i.e.* 1° for each 180 feet of ascent, to the height of a mile or more. On fair days with clouds, the fall is at the above rate to the base of the clouds; in the cloud the rate of fall is slow, and it is still slower above the cloud. It appears that the diurnal change in temperature in the free air nearly disappears at about 2500 feet, which is much lower than has been hitherto supposed. During calm nights there is a marked inversion of temperature, so that the air near the ground is usually much colder than at the height of a few hundred feet; indeed, on some occasions the air may be colder at the ground than at the height of several thousand feet.

Daily kite flights confirm the theory that temperature changes in the upper air are cyclonic in character, being due to the passage of "warm and cold waves," which are more strongly felt in the upper air than near the ground. The changes with altitude which precede a "warm wave" are these: during the day a decrease of temperature at the adiabatic rate from the ground up to more than 1000 feet, then a sudden rise of temperature, amounting to perhaps 15°, followed by a slow fall. Clouds form when the dew-point of the warm current, which overflows the cold current, is sufficiently high. Such conditions announce the arrival of a "warm wave" eight to twenty-four hours in advance of its appearance at the earth's surface. The conditions which indicate the coming of a "cold wave" are a rapid fall of temperature, which exceeds the adiabatic rate up to about 1000 feet, and above that is at the adiabatic rate to 3000 feet or higher. During the prevalence

of the cold wave the temperature at the height of a mile, which is sometimes its upper limit, may be 25° or 30° lower than at the ground. After the "cold wave" has passed, and with the coming of a South-east storm, the temperature rises rapidly up to a height of 1000 or 2000 feet, and then slowly falls. Cloud usually occurs where the temperature begins to fall, and sometimes this cloud extends downwards to the earth as fog. The relative humidity generally increases to saturation in the clouds, and above them rapidly decreases. In clear weather there may be no change of relative humidity with altitude, as during "cold waves," or, with no change of temperature vertically, both the absolute and relative humidity may decrease rapidly with increase of altitude, as is the case in areas of high barometric pressure. At the height of half a mile the diurnal changes of relative humidity are the inverse of those at the ground. In brief, then, during fair weather in the upper air the days are relatively cold and damp, while the nights are warm and dry, as compared with surface conditions. Electricity is usually noticed on the kite wire whenever the altitude of the kites exceed 1700 feet. At higher altitudes, as well as during snowstorms and near thunderstorms, the potential increases, and is sufficient to cause strong sparkling discharges. It therefore appears to be only necessary to tap the great atmospheric reservoir to obtain an inexhaustible supply of electricity, which, perhaps, may be applied to the service of man. Kites are frequently employed on Blue Hill to measure the heights of certain low and uniform clouds which could not be measured by either photographic or visual theodolites. From the traces of the barometer and hygrometer the thickness of clouds may be determined.

Advantages of Kites over Mountain Stations and Balloons.

From the foregoing it would appear that the former toy, the kite, has been made at the Blue Hill Observatory of the greatest importance for meteorological investigation. Stations on mountains, maintained at great cost, probably alone can give long-continued observations at a constant height above the general level of the earth; but these observations are all affected, to a greater or less extent, by the mountain itself, and so do not represent the true conditions of the free air. To determine these, from time to time, balloons have been used; but the results, from a meteorological standpoint, have been incommensurate with the expense and risk incurred. Nevertheless, at the International Meteorological Conference at Paris in 1896, balloons were recommended, both captive and free with aeronauts, and free balloons to carry only self-recording instruments much higher than man can live. The successful experiments with kites at Blue Hill led to the recommendation that this method also should be included in the international scheme for exploring the atmosphere. An International Committee, of which the writer is the American member, was appointed to carry out the recommendations. International co-operation in the work with balloons has been secured on the Continent of Europe, but in America attention has been given chiefly to kites, which, up to a height of at least 10,000 feet, present these advantages over free balloons, whenever there is wind:—

1. Economy in installation and working.
2. Accurate determination of height by angular measurements.
3. Adequate exposure and ventilation of the thermometers, which in a balloon are bathed in heated and stagnant air. Therefore the temperatures observed at a given height in a balloon are generally warmer during the ascent than during the descent, which is not the case with kites.
4. The possibility of making frequent ascents and descents permits observations to be obtained almost simultaneously in different air strata, and nearly over a station at the ground where there may be instruments recording simultaneously.

Captive balloons, besides being more expensive than kites, under the most favourable conditions cannot attain nearly so great heights, on account of the weight of the cable necessary to control them. On the few occasions when the wind is lacking near the ground, there can be substituted the "kite balloon" already tried in Germany, which will always carry instruments to moderate heights, because it is not driven down, like the ordinary captive balloon, by the high winds which prevail in the upper air.

The advantages of kites are now becoming generally recognised. The United States Weather Bureau has already equipped twenty stations with kite appliances to obtain synoptic data daily at the height of a mile in the free air for forecasting. M. Teisserenc de Bort is equipping his observatory near Paris with kites and apparatus similar to those at Blue Hill. General Rykatchew, at St. Petersburg, has lifted anemometers with kites, and M. Tacchini now proposes to employ kites at his mountain stations in Italy. Prof. Assmann, in the new section of aeronautical-meteorology of the Prussian Meteorological Institute at Berlin, intends to make important use of kites. At the recent meeting of the International Aeronautical Committee at Strassburg, the writer had the honour to report on the subject, and it appeared natural for the Conference to recommend that all central observatories should employ this method of investigation as being of prime importance for the advancement of meteorological knowledge. It is interesting to learn that experiments with kites have been undertaken in Scotland, which, it will be recalled, was the birthplace of scientific kite-flying, and it is to be hoped that the example of Messrs. Mossman and Anderson will be followed in England, where, as has been stated, Mr. Archibald revived the use of kites for meteorological observations fifteen years ago.

ADDENDUM.

The Highest Kite Flight.

The average height of the meteorograph above Blue Hill in the flights during August 1898 was 7800 feet, and on August 26 the meteorograph was raised 360 feet higher than ever before, its altitude, determined trigonometrically, being 11,444 feet above Blue Hill, or 12,074 feet above the adjacent sea. The meteorograph was suspended from the top kite, a Lamson aero-curve with 71 square feet of lifting surface; and four kites of the modified Hargrave form, with a combined lifting surface of 149 square feet, aided to lift the wire, which was

nearly 5 miles long, and weighed 75 lbs. The total weight of the kites, lines, and apparatus in the air was 112 lbs.

The meteorograph left the ground at 10.40 a.m., attained its greatest height at 4.15 p.m., and reached the ground at 8.40 p.m. It passed through cumulus clouds about three-quarters of a mile from the earth,

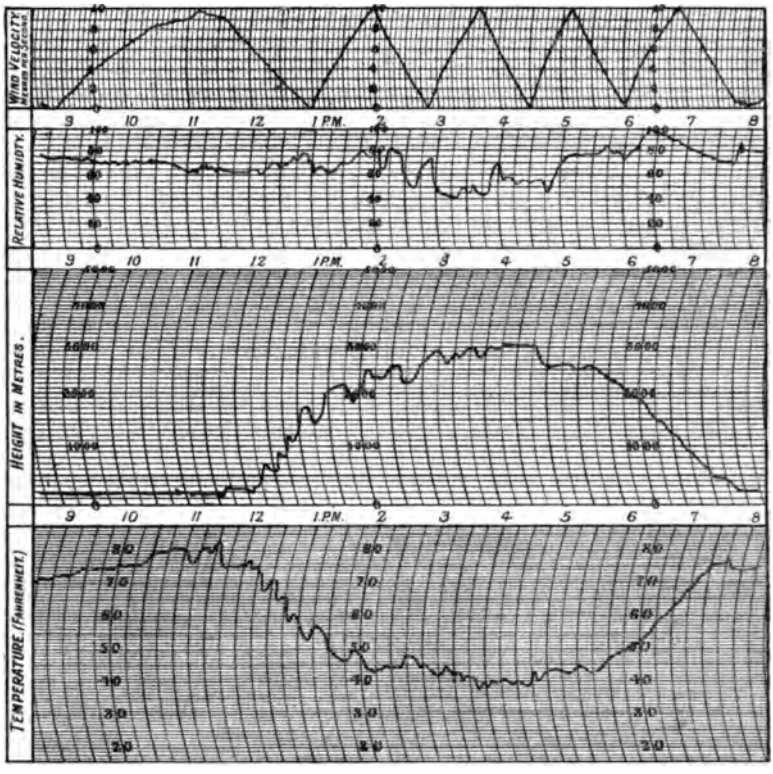


FIG. 3.—Kite Meteorogram, Blue Hill Observatory, August 26, 1898.

and above them the air was found to be very dry. The maximum wind velocity, 40 miles an hour, occurred at the height of 11,000 feet, while 400 feet higher it blew at the rate of 32 miles an hour from the South-west. On the hill at this time the wind was West, and its velocity was 22 miles an hour. There the temperature of the air was 72° when it was 38° in the free air 11,444 feet above.

DISCUSSION.

The President (Mr. F. C. BAYARD) said the thanks of the Society were due to Mr. Rotch for bringing the interesting results of his kite-work before them.

Mr. R. C. MOSSMAN, in a note, said—The kite-flying experiments hitherto carried out in Edinburgh have been entirely confined to testing kites of various

sizes and the apparatus generally. Four successful and one unsuccessful ascensions have been made with kites of the Blue Hill pattern. The largest kite employed was about 6 feet high and weighed 11½ lbs. It would not rise with a wind blowing under 12 miles an hour, and was too heavy: a reduction of from 3 to 4 lbs. could easily be effected. On one occasion three kites were sent up, and although the sky was cloudless the highest kite, which was 600 feet above the second one, came down in a soaking condition, while the other two were perfectly dry. The last ascension was unsuccessful, the kite breaking away when about a mile high. It travelled three and a half miles before touching ground, and was recovered in a practically uninjured condition. The cause of the accident was a defect in one of the fastenings, which had worked loose in the strong gale which was then blowing. Piano wire has been regularly used, breaking strain 280 lbs. No instruments have as yet been sent up, as an application for a small Government grant had been made. Unfortunately the application has not been successful; but as intimation to this effect was only received ten days ago, there has been no time as yet to procure the baro-thermo-hygrograph specially constructed by M. Richard of Paris. We further intend to attach wires to the kite, connected with an electrometer, with the object of ascertaining the potential existing in condensing and dissipating clouds. Some work in this connection has been done by Prof. Michie Smith on the summit of Dodabetta, India. He finds that the potential on the edge of a dissolving mist is lower than the normal, while in a condensing mist it is higher than the normal. It will be of interest to ascertain whether the same occurs in the free air. Such observations may be expected to be of considerable value in connection with the discussion of the cause of thunderstorms. The success of the Edinburgh experiments, so far as carried out, is entirely due to the energy and liberality of Mr. John Anderson (late of Owensboro, Kentucky), who has directed the operations from the first.

Capt. BADEN-POWELL said that he was pleased with the opportunity afforded him of hearing the paper, as there was much in it that was purely original. The methods in England were widely divergent from those employed at Blue Hill Observatory. His own pattern of kite was different from any type that had been described in the paper. He had experimented with several shapes, and had developed one which seemed to him in most respects satisfactory. One great difference between his own and the pattern employed in America was, that the former was much lighter for the same area. He could not compare their flying capabilities, as he had no experience whatever of the American pattern; but he was certain that he could raise his kites in a much lighter air current than that required by Mr. Rotch to elevate his patterns, viz. a velocity of 12 miles per hour. In fact, he had never experienced any difficulty in this respect, his lighter kites rising with ease, even in a dead calm. Walking just to give them a start was all that was needed, and a gentle air of about 4 miles per hour was quite sufficient to raise his large kite, the area of which was 100 square feet. His light kites weighed 6 lbs., and his heaviest 10 lbs., so that even the heaviest compared favourably with those used at Blue Hill; and he thought they would prove equally suitable for meteorological purposes by reason of their easy ascent, providing they fly as well. He did not think the instruments would be in any way damaged, as though the kites were sometimes unsteady they never collapsed entirely. He had never sent up meteorological instruments, but had frequently sent up instruments of a similar delicate nature, such as photographic apparatus, etc. He did not himself use wire, chiefly because it had not hitherto been his object to attain any very great elevation. Almost any ordinary day would be suitable for kite-flying, and with a good equipment and a good open space—the latter a very necessary essential—he thought it should prove of great value to meteorology. Mr. Rotch had demon-

strated the advantages of kite-flying over balloons for these purposes, and he (Capt. Baden-Powell) cordially agreed with him in this respect.

Mr. R. STRACHAN inquired what type of instrument was employed in the meteorograph to obtain the record of relative humidity of the air.

Mr. F. GASTER remarked that the necessity for high-level observatories is undeniable, but that in dealing with the atmospheric circulation there is in mountain observations the disadvantage ever present of the interference of high masses of ground, which, by deflecting the air, must form currents of a purely local character, and which could not be classed as the general condition. He thought, therefore, that observations with high-flying kites must be of great use in the question of atmospheric circulation, rising as they did above local influences. If flown from altitudes such as Ben Nevis, they would probably show how local the currents at the summit of such mountains are, like half those at the surface of the lower-lying regions, and would enable us to come to sound conclusions as to the movements taking place in the high as compared with the low parts of the atmosphere. Cloud observations are often of great assistance, but the movements above are so frequently shut out by masses of cloud or fog in the lower strata that their value is very frequently done away with, and particularly when, in the present state of our knowledge, they would be most valuable.

Mr. G. J. SYMONS said he regarded the paper as of exceptional value, being well backed up by references. What he had always thought was the difficulty in high kite-flying, viz. that of raising the kite, according to Capt. Baden-Powell, scarcely existed. He hoped that Capt. Baden-Powell would lend one or two blocks of his pattern of kite, so that his pattern might appear in the *Quarterly Journal* along with those used by Mr. Rotch. [See page 263.]

Mr. A. L. ROTCH, in a note to the Secretary, replied that the kites of Capt. Baden-Powell had lately been tried at Blue Hill. Although they flew in a lighter wind than did the Hargrave kites, yet they were not sufficiently stable in winds of varying velocity without using side-lines, which precluded the attainment of great heights. The relative humidity of the air was recorded in the meteorographs through the agency of a bundle of human hairs.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 18, 1898.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

HORATIO HALIBURTON BENTLEY, 5 The Campsbourne, Hornsey ; and FREDERIC GEORGE HAWORTH, M.B., C.M., D.P.H., Vale House, Darwen, were balloted for and duly elected Fellows of the Society.

The following communications were read :—

"THE FREQUENCY OF RAINY DAYS IN THE BRITISH ISLANDS." By ROBERT H. SCOTT, M.A., F.R.S. (p. 217).

"THE ABNORMAL WEATHER OF JANUARY 1898." By FREDERICK J. BRODIE, F.R.Met.Soc. (p. 229).

June 15, 1898.

Ordinary Meeting.

FRANCIS CAMPBELL BAYARD, LL.M., President, in the Chair.

The President stated that he had, with great regret, to announce the death of Mr. Perigal, which had occurred on June 6.

The following resolution, moved by Mr. A. BREWIN, and seconded by Mr. E. E. DYMOND, was unanimously adopted:—

> "The Council and Fellows of the Royal Meteorological Society have heard with deep regret of the death of their esteemed Treasurer, Mr. Henry Perigal, F.R.A.S.
>
> "He joined the Society on June 4, 1850, was elected on the Council on December 22, 1851, and was appointed Treasurer on May 24, 1853, which office he held continuously until his death on June 6, 1898—a period of 45 years.
>
> "The Council and Fellows desire to record their high sense of the valuable service which Mr. Perigal rendered to the Society for so many years, and of the keen interest which he took in the discharge of his duties.
>
> "The Council and Fellows desire to express their sincere sympathy with his brother, Mr. Frederick Perigal, and other members of the family in their bereavement."

ROBERT STOKES BEAGLEY, Suva, Fiji; and
MATTHEW WILLIAM DUNSCOMBE, 10 St. Augustine's Parade, Bristol,
were balloted for and duly elected Fellows of the Society.

The following communications were read:—

"FREQUENCY OF NON-INSTRUMENTAL METEOROLOGICAL PHENOMENA IN LONDON WITH DIFFERENT WINDS FROM 1763 TO 1897." By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc. (p. 238).

"THE EXPLORATION OF THE FREE AIR, BY MEANS OF KITES, AT BLUE HILL OBSERVATORY, MASS., U.S.A." By A. LAWRENCE ROTCH, S.B., A.M., F.R.Met.Soc. (p. 250).

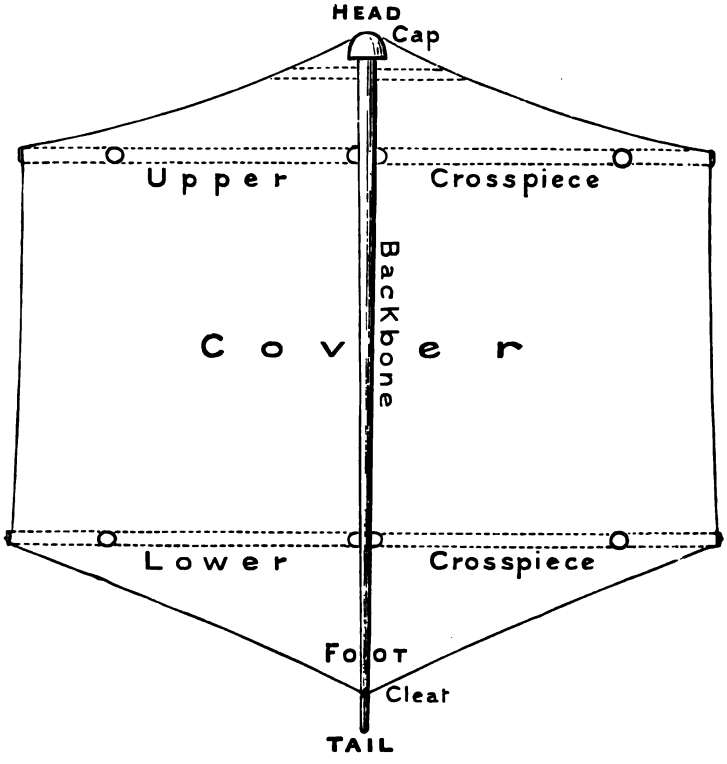
CORRESPONDENCE AND NOTES.

The Baden-Powell Kites.—At the meeting of the Society on June 15, Capt. Baden-Powell, in the discussion on Mr. Rotch's paper (p. 260), gave an account of the experiments which he had made with kites in this country; and a hope was expressed that he would permit some illustrations of his pattern of kite to appear in the *Quarterly Journal* along with those used by Mr. Rotch. Capt. Baden-Powell has sent the following particulars about the use of his patent kites. These kites are made in three sizes, 6 feet, 12 feet, and 24 feet high. When great power is required, either several smaller kites may be attached to the same line, or one larger one used. The smallest size would, as a rule, be able to lift light weights, such as signalling apparatus, a photographic camera, etc., while the largest size will lift a man in a good wind.

The following directions should be carefully noted and acted on, else not only may the kites not fly well, but they may be easily damaged and broken:—

To Spread Kite.—Unroll kite and lay on ground; place top of the backbone

in the cap at the top of the cover. Stretch out kite and pull foot end as far as possible along the backbone, and fix tail lanyard on cleat. See bridle lines all



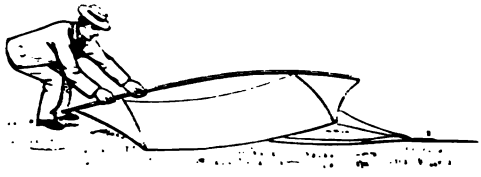
correct. ("Bridle" consists of all the strings attached to the kite and connecting it to the ground lines.)

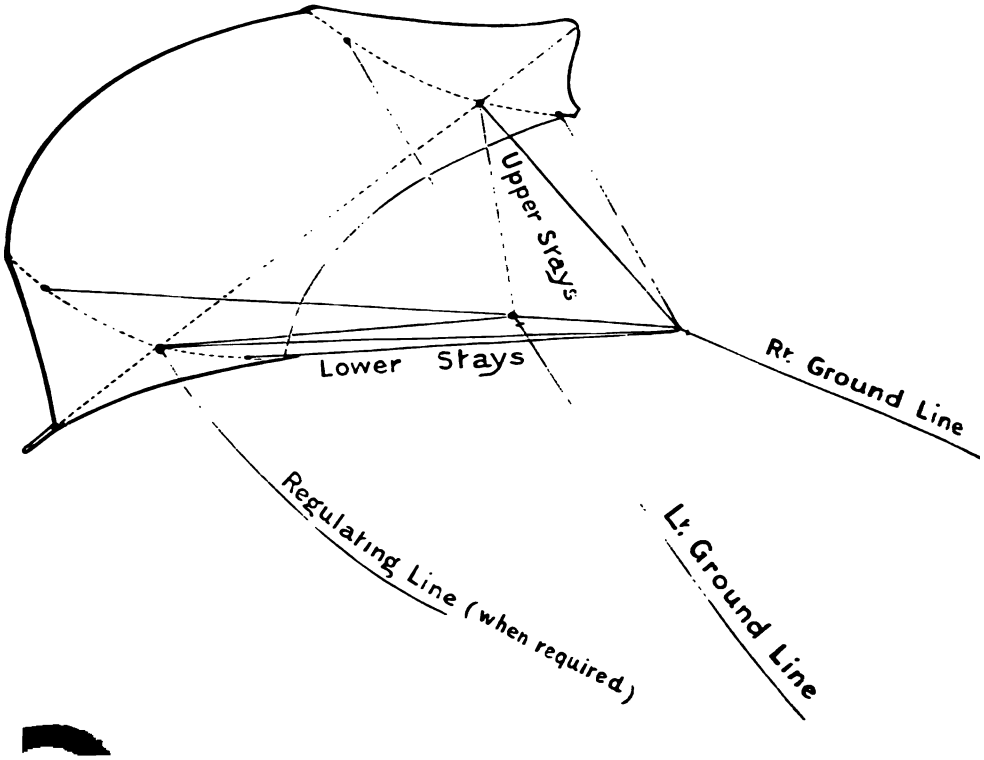
Management of Kite on the Ground.—Kites are always easy enough to manage, however large, if two points are always remembered—1. Keep kite *flat*, *i.e.* parallel to the ground ; and 2, always keep on *windward* side of kite. If a kite should by accident be lifted up by the wind, do not force it down, but let it turn over of itself. Sometimes a kite if badly started will roll over on the ground with its head downwards, and will remain thus pressed by the wind. Approach kite from windward side, lift head, and carry it backward *towards* wind. It will then fall flat on ground, but face upwards. To turn kite upside down, get string slack (by walking towards wind), lift up front edge till wind gets underneath, keep down one side of kite and let wind blow it right over, the ends of the crosspieces resting on the ground. To carry kite about, hold by front edge of cover, one hand on each side of cap ; as you walk along, wind will get under kite, and it will float horizontally. If you have to

be at the lee side of a kite, lift that side up slightly, so that the wind presses the kite downwards to the ground, else the wind may get under front edge and lift kite up. Avoid sitting or standing on *lee* side of kite as it lies on the ground, as, if windward side is suddenly lifted by gust, the frame will probably be broken.

To Adjust Bridle.—These kites are fitted for one line or two. Two lines are used for strong and gusty weather, or for steering with. The bridle consists of two sets of "stays," upper and lower. The proportion between the length of these varies, but an average amount is 1 : 1·3 (the length between points of attachment being 1). As a rule the *lighter* the wind the *flatter* the kite should float, that is, the *shorter* the *upper* stay as compared with the lower. In strong winds they can be nearly equal in length.

To Start Kite.—Select site where there are no trees or buildings to windward. Spread out good length of line along the ground in direction of wind, fix end to peg, tree, or other object. Attach other end to bridle. If using two lines fix at points as far apart as the length of the lines. Kite lying on its face, head to wind. Get round to tail end of kite, pull it along ground till line is quite taut. Place foot on tail end of backbone, and reaching out as far as possible gently lift backbone so as to raise head off ground, and let wind under. As kite rises keep hold of tail end till quite upright and steady, and then let go. If kite leans over to one side, move over to that side with tail, so as to keep tail under centre of kite.





Flying the Kite.—If the kite moves greatly from side to side and lower part shivers, it shows adjustment of bridle is too *flat*. If very wild when on *one* line, put on the *two*. If in light airs kite swings slowly and pendulum-like, it implies kite is too heavy, and will probably sink down. Steady tugs on the line will make kite ascend. If it can be got up about 100 feet it will usually float there, even if calm below.

To Get Kite Down.—Walk along under string, pulling it down hand over hand. It is preferable to have pulley always on line with cross-stick as handle. If circumstances require kite to be often taken down, it is best to fit "regulating line."

To Fold Kite Up.—Lay kite flat on face, cast off lines, undo tail lanyard. Holding lower cross-piece, advance towards head till both cross-pieces lie together. Unship backbone out of cap, and turn it round to lie alongside cross-pieces (stays will run through eyes). Arrange all poles to be of equal length. Shake down cover to hang straight below. Step back a couple of paces so that bridle is spread on ground before you, then roll up all.

We are indebted to The Military Equipment Stores Co., Ltd., for the use of the above blocks.

Sunstroke and Meteorological Conditions. — The Chief of the U.S. Weather Bureau, in his recent Annual Report, refers to the study made by Dr. W. F. R. Phillips of the meteorological conditions associated with the occurrence of sunstroke.

From trustworthy information received in response to a circular sent out August 20, 1896, it appeared that 2038 deaths occurred during that month which were directly attributed to sunstroke, as the term is originally used and accepted. Although this number of deaths was unusually large, there was reason to suppose that the actual number of fatalities from the intense heat was much larger; and accepting the usually stated ratio of cases and deaths, the number of persons that must have suffered in greater or less degree was something enormous. In 841 cases of sunstroke, the clinical histories of which were obtained with more or less exactness, the fatality was 16·6 per cent, and were this rate assumed as the index of fatality that obtained in general during August 1896, the 2038 deaths would have represented the occurrence of 12,277 cases of sunstroke of varying severity. From a comparative study of the sunstrokes and the weather prevalent during their occurrence, the following conclusions regarding the relation and influence of the meteorological conditions were reached:—

a. That the number of sunstrokes followed more closely the excess of temperature above the normal than it did that of any other meteorological condition.

b. That the number of sunstrokes did not appear to sustain any specific relation to the relative humidity.

c. That although the absolute humidity was greatest during the maximum of sunstrokes, yet it did not appear that its variation influenced the number of cases.

d. That the other recorded meteorological conditions, *i.e.* the atmospheric pressure, wind, rain, and state of weather, did not show any features that could be regarded as of etiological significance.

Inasmuch as there appeared to be a closer association between the course of the sunstroke and the course of the atmospheric temperature than between any other meteorological element or condition, an attempt was made to ascertain, if possible, what degree of temperature was necessary or most likely to excite sunstroke. An examination of the different statistics appeared to show that there was empirical evidence for assuming that each locality had for its

acclimated inhabitants a particular sunstroke temperature or range of temperature, and for adopting as a provisional index of the sunstroke temperature the normal daily maximum temperature of each climate. This provisional standard applied to the cases of sunstroke as reported in the cities of New York, Boston, Philadelphia, and Washington, from which places the statistics were most numerous, gave the following results :—

In New York City 96 per cent of the cases occurred with daily mean atmospheric temperatures equal to or slightly above the normal maximum temperature for August (the period in question). In Boston and Philadelphia 91 per cent, and in Washington 77 per cent, of the cases occurred under like conditions of temperature.

In the light of these results, the following working hypothesis was proposed : Sunstroke becomes imminent during the summer months when the mean temperature of any one day, or of several successive days, becomes equal or nearly equal to the normal maximum temperature for the period. Also, an attempt was made to determine, by using such statistics as were accessible for other years, how far the hypothesis above stated could be depended upon as a criterion of impending danger from sunstroke, with the result that it appeared to be a fairly good index for the eastern and central portions of the United States. No statistics were accessible for the States of the Western plateaus. But, with respect to the above hypothesis, this caution is to be kept in mind : that although the hypothesis embodies certain plausible climatological conditions, it was evolved simply as an empiricism based upon quite a large number of facts, and that it does not rest upon a satisfactory knowledge of all the factors involved, and that even before it can be said to represent accurately an empirical relation it must be corroborated by a larger mass of statistics than are at present accessible.

Meteorology of the Antarctic Regions.—On February 24, the Royal Society held one of its special meetings for Discussion, at which, in addition to the Fellows of the Society, other specialists are invited to take part. The subject was "The Scientific Advantages of an Antarctic Expedition." Sir J. Murray, in the opening paper, referring to the atmosphere, said :—

"One of the most remarkable features in the meteorology of the globe is the low atmospheric pressure at all seasons in the southern hemisphere, south of latitude 45° S., with the accompanying strong Westerly and North-westerly winds, large rain- and snow-fall all round the South Polar regions. The mean pressure seems to be less than 29 ins., which is much lower than in similar latitudes in the northern hemisphere. Some meteorologists hold that this vast cyclonic system and low-pressure area continues south as far as the pole, the more southerly parts being traversed by secondary cyclones. There are, however, many indications that the extreme South Polar area is occupied by a vast anticyclone, out of which winds blow towards the girdle of low pressure outside the ice-bound region. In support of this view it is pointed out that Ross's barometric observations indicate a gradual rise in the pressure south of the latitude of 75° S., and all Antarctic voyagers agree that when near the ice the majority of the winds are from the South and South-east, and bring clear weather with fall of temperature, while Northerly winds bring thick fogs with rise of temperature.

"All our knowledge of the meteorological conditions of the Antarctic is limited to a few observations during the midsummer months, and these indicate that the temperature of the snow-covered Antarctic continent is even at that time much lower than that of the surrounding sea. The anticyclonic area at the South Pole appears therefore to be permanent, and when in winter the sea-ice is for the most part continuous and extends far to the north, the anticyclonic

area has most probably a much wider extension than in summer. This is indicated by the South-easterly winds which at times blow towards the southern point of the American continent in June and July.

"All observations in high southern latitudes indicate an extremely low summer temperature. In winter we have no direct observations. The mean of Ross's air temperatures south of latitude 63° S. was 28°·74 F., which is about the freezing point of sea-water, and his maximum temperature was 43°·5. Both Wilkes and Dumont d'Urville observed pools of fresh water on several icebergs, and when sailing along the ice barrier Ross saw 'gigantic icicles depending from every projecting point of its perpendicular cliffs,' so it is probable that extensive melting sometimes takes place.

"In the latitude of the Antarctic circle the air is frequently at or near the point of saturation, and precipitation takes place in the form of rain, sleet, snow, or hail. Most of the observations near the ice-covered land show, however, a much drier atmosphere, and in all probability precipitation over the Antarctic continent takes place in the form of fine snow crystals, such as is recorded in the interior of Greenland.

"There would appear, then, to be good reasons for believing that the region of the South Pole is covered by what may be regarded practically as a great permanent anticyclone, with a much wider extension in winter than in summer. It is most likely that the prevailing winds blow out from the Pole all the year round towards the surrounding sea, as in the case of Greenland; but, unlike Greenland, this area is probably seldom traversed by cyclonic disturbances.

"But what has been stated only shows how little real knowledge we possess concerning the atmospheric conditions of high southern latitudes. It is certain, however, that even two years' systematic observations within these regions would be of the utmost value for the future of meteorological science."

In the discussion which followed, Dr. A. Buchan spoke on the relation of atmospheric pressure to prevailing winds. He stated that, according to Ferrel's theory of atmospheric circulation on the globe, as set forth by Professor Davis, an area of low pressure existed over the South Pole, towards which surface winds blew in on all sides. But the observations of all Antarctic expeditions which had crossed the polar circle showed that the barometer continued to rise as they proceeded southward, and that the winds blew, with scarcely an exception, from a Southerly quarter, or outward from the Pole. This indicated that a region of high atmospheric pressure was central over the South Pole, and the climate there ought to be free from excessive precipitation, and favourable to exploration. Were Ferrel's theory correct, the excessive precipitation which would necessarily result would render the Antarctic region almost inaccessible to the most intrepid explorer. A well-equipped Antarctic expedition was necessary in order to make observations which should fix the position of the great ring of low atmospheric pressure surrounding the globe in the southern ocean, a feature as important in oceanography as it was in meteorology.

Annual Range of the Surface Temperature of the Ocean.—At the meeting of the Royal Geographical Society on February 28, Sir John Murray read a paper on the "The Annual Range of Temperature in the Surface Waters of the Ocean, and its relation to other Oceanographical Phenomena," which he illustrated by a map constructed from the extreme temperatures in every two-degree square. The lines on the map are drawn for intervals of 5°, and different shades of colour are used for intervals of 10°. The annual range of surface temperature in the ocean within any particular two-degree square does not exceed 53°; this greatest annual range being found off the banks of Newfoundland in the Atlantic, and in the Japan seas in the Pacific—at places where

the surface is occupied by cold waters coming from Polar areas at one season, and by warm waters coming from tropical areas at another season. The lowest recorded temperature reading at the surface of the sea is 26° in the North Atlantic, eastward of Nova Scotia; and the highest reading in the open ocean is 90°, recorded in the tropical Pacific, both north and south of the equator, though readings of 94° and 96° are recorded in the Red Sea and Persian Gulf respectively. The greatest known range of temperature of the surface waters throughout the world is thus 70°.

Atlas of Cloud Forms.—Capt. C. D. Sigsbee, the late U.S. Hydrographer, has recently published a little book containing 16 coloured plates of illustrative Cloud Forms for the guidance of observers in the classification of clouds. Capt. Sigsbee says that the inadequacy of the old classification of clouds, either for identification or record, and the increasing attention given to clouds as signs for forecasting the weather, have led to the adoption of the present classification by the Hydrographic Office. The classification, nomenclature, and descriptive text are derived from the *International Cloud Atlas* (Paris, 1896), but the plates are from original paintings made for the Hydrographic Office by Mr. Cronau. The standard classification includes 10 cloud types, which are shown on the first 10 plates. Certain modifications of these types are shown on the remaining 6 plates. Each plate embraces the horizon and enough extension of view to show cloud perspective.

RECENT PUBLICATIONS.

Annuaire de la Société Météorologique de France. Janvier—Septembre 1897. Vol. XLV. 4to.

The principal articles are :—Sur une pluie d'encre : par G. Guilbert (3 pp.). This is an account of the black rain which fell in the departement of Calvados on October 21, 1896. The origin of the colour of this rain appears to have been due to a large fire which occurred in the town of Caen, a fire which destroyed a large quantity of wood.—Résumé des observations centralisées par le service hydrométrique du bassin de la Seine pendant l'année 1896 : par M. Babinet (56 pp.).—Sur les observations pluviométriques de Jules Clos, à Sorèze (Tarn), pendant les vingt années 1869-89 : par V. Raulin (6 pp.).—Sur la constitution de l'atmosphère et la brume crépusculaire : par C. Ritter (45 pp.).

Journal of the Scottish Meteorological Society. Vol. XI. Third Series. Nos. xiii. and xiv. 8vo. 1898.

In addition to the Reports of the Council and the meteorological tables for the years 1895 and 1896, this contains four papers, viz. :—(1) The mean atmospheric pressure and temperature of the British Islands : by Dr. Buchan (41 pp. and 26 coloured maps). In this paper the author gives the monthly and annual means of pressure and temperature from about 400 stations for the 40 years 1856-95. In every month the isobars are deflected more or less from straight lines, the deflections in each case being readily traced to the respective influences, varying with season, of the land and water of the region comprising the British Islands on the distribution of the pressure. The influence of the land is to lower the pressure slightly in the warmer months, and to increase it in the colder months of the year, just as takes place on a large scale over the continents of the globe during the summer and winter months. In all seasons, on the other hand, the influence of the ocean is to lower the pressure, and this depressing influence is greatest near the coasts of the Atlantic and of

the North Sea. Owing, however, to the "mediterranean character" of the Irish Sea, the deflections of the isobars, as they cross it, stand out as a very striking feature of the curves, indicating in an impressive manner some of the more prominent causes which regulate the geographical distribution of atmospheric pressure over the globe.—(2) On the determination of the temperature of saturated steam, and the production of higher fixed temperatures by the condensation of steam on salts and in saline solutions: by J. Y. Buchanan, F.R.S. (16 pp.)—(3) The Aurora Borealis in London from 1707 to 1895: by R. C. Mossman (7 pp.). Auroras are most frequent in October and April, and rare in December and June.—(4) Change of temperature with height during anticyclones on Ben Nevis and at some continental stations: by R. T. Omond (7 pp.). In concluding this article the author says: "From all these observations—both at varying heights in Switzerland, and in rapid changes from foggy to dry air at the upper surface of clouds—it seems well established that, in the class of anticyclones which bring out the Ben Nevis barometer higher than the true pressure when reduced to sea-level, the cold of the lower atmosphere is confined to a small vertical height, and that the reversal of temperature gradient, indicated by a high-level station being warmer than a low, all takes place in the cold damp air, or just immediately above it; the great mass of warm dry air which forms the body of the anticyclone having normal vertical temperature gradients, indeed showing, if anything, a decrease of temperature with height rather more rapid than usual. How far the converse of this holds—that in a cyclonic area, when the Ben Nevis barometer comes out lower than the true pressure at sea-level, the intermediate air is colder than the mean of summit and base—has not yet been determined. The more rapid changes of cyclonic weather, and the frequency of high winds, with their purely mechanical depression of the barometer, introduce complications that are absent in the anticyclone."

Law of Storms in the Eastern Seas. Investigated by W. DOBERCK, Director of the Hong Kong Observatory. 8vo. 1898. 40 pp.

The first chapter treats of the Law of Storms, and was originally published in Hong Kong in September 1886. The other subjects dealt with are:—How to manage a ship in a typhoon; Weather forecasts and storm warnings; On the different classes of typhoons, and the seasons of the year in which they appear; and Winter typhoons in the southern part of the China Sea.

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. March—August 1898. 4to.

The principal articles are:—Ueber einige meteorologische Beziehungen zwischen dem Nordatlantischen Ocean und Europa im Winterhalbjahr: von Dr. W. Meinardus (21 pp.). This paper deals with the ideas put forward by Dr. O. Petterson as to the relation between the temperature of the Gulf Stream, or, properly speaking, the eastern part of the North Atlantic, and the winter climate of Western Europe. Dr. Meinardus seeks to establish by careful investigation the truth of this principle, but he does not show how regular observations of Atlantic temperature can be collected in sufficient quantity, or in sufficient time, to be used in forecasting the character of each winter.—Ueber die Redaktion kürzerer Reihen von Niederschlagsmessungen auf die langjährige Reihe einer Nachbarstation: von Dr. J. Hann (13 pp.). This is an answer to a paper by Dr. P. Schreiber which appeared in 1896 among the publications of the Saxon Meteorological Department. Dr. Schreiber makes the statement that Dr. Hann had propounded a law that the relation between the quantities of rain at adjacent stations is always a constant. To show how easily a mis-statement is accepted as truth, Prof. Hammer, in *Petermann's Mittheilungen* for 1897, accepted

Dr. Schreiber's statement without question. Dr. Hann now points out that he never propounded any law such as Dr. Schreiber alleges, and shows that what he did say was what is accepted by every one, except perhaps Dr. Schreiber, as true. Dr. Schreiber proceeded to show that this alleged law is not true because it does not agree with theory; and Dr. Hann rejoins that many meteorological phenomena have not yet received a full theoretical explanation, *e.g.* the diurnal range of the barometer. Dr. Hann closes the paper with a few tables giving for a series of twelve stations, extending from Austria to Seathwaite and the Stye in Cumberland, the actual figures showing how very constant are the differences between pairs of stations, if the stations are properly selected and the number of years sufficient. He takes 30 years.—Temperatur und Feuchtigkeit der Luft auf freiem Felde, im Kiefern- und Buchenbestande: von J. Schubert (7 pp.). This is an account of a series of experiments carried on at Eberswalde in beech and fir plantations. The Assmann ventilating apparatus was used and compared with various screens. We are glad to see that the improved Stevenson screen—we presume that suggested by the Royal Meteorological Society—comes out best; and it is stated that at Potsdam this is placed close to a hut and not in open ground. The figures are worth careful study.—Ueber Zufluss und Abfluss der Luft in Cyklonen und Anticyklonen: von Dr. W. Köppen (8 pp.). This is an attempt to deduce mathematically the causes of the production and maintenance of depressions, and especially of secondary depressions, dealing with the questions of cyclones with warm and with cold centres respectively. It does not, however, appear that the results of the reasoning can be utilised in forecasting.—Beiträge zur Kenntniss der Niederschlagsverhältnisse der Eifel: von P. Polis (6 pp.). This is a discussion of the rainfall of Western Germany. The maximum fall is at Botrange and Monte Rigi a little north of Malmedy. The amount is about 42 ins.—Achte allgemeine Versammlung der Deutschen Meteorologischen Gesellschaft zu Frankfurt a. M., am 13-16 April 1898 (16 pp.). This is a report of the meeting of the Society which was held at Frankfort-on-the-Main in April, with abstracts of the various papers read.—Ueber die Einwirkung von Flussläufen auf eine darüber befindliche Wolkendecke: von Dr. F. Erk (9 pp.). This is a detailed account of some balloon ascents made from Munich, with a description of the way in which the different river courses were reproduced in cloud above them.—Die erste Konferenz der internationalen aëronautischen Kommission: von Dr. F. Erk (8 pp.). This is an account of the meeting of the Balloon Committee appointed by the International Meteorological Conference of 1896. The meeting was largely attended, and the chief points discussed were the improvement of meteorological apparatus suited for balloon work. Experiments were also made with kite balloons, which, however, were much more elaborate articles than those originally employed by Mr. E. D. Archibald in 1882. Another point which was discussed was the best method of speedily emptying the balloons of gas.—Die Temperaturabnahme mit der Höhe in den niederösterreichischen Kalkalpen: von Dr. W. Trabert (13 pp.). This is a comparison of the results of temperature observations for the period 1851-80 in the Austrian Alps, chiefly as to the influence exerted by the position of the stations on the "weather" or the "lee" side of the range. As a general rule, the decrease of temperature with elevation is more regular on the lee than on the weather side.—Experimentelle Beiträge zum Studium der Wirbelbewegungen in den Wolken: von K. Mack (18 pp.). This is an account of experiments to reproduce in liquids by means of a jet of coloured liquid, delivered at the base of a glass cylinder, the phenomena of turreted cumulus clouds, particularly such formations as Herr Streit described in the *Zeitschrift* for January 1896, from the neighbourhood of Venice (see *Quarterly Journal*, vol. xxii. p. 235). Herr Mack certainly by this method reproduces vertical columns spreading out at the top into mushroom shapes, and he proceeds to

argue that this is the simplest explanation of the formation of what some call "thunderheads."

Observations upon the Topography and Climate of Crowborough Hill, Sussex. By C. LEESON PRINCE, M.R.C.S., F.R.A.S. Second Edition. 1898. 8vo. 312 pp.

The first edition of this work was published in 1885, and consisted of 104 pages; the second edition is therefore a book three times the size of the first. Mr. Prince gives tables of the results of his observations at Crowborough from 1874 to 1897, and also an interesting record of various natural phenomena from January 1, 1871, to December 31, 1897. The book is illustrated with reproductions of snow-crystals, hailstones (actual size), as well as views of the neighbourhood. Mr. Prince concludes his work with a chapter on prognostics of atmospheric changes as recorded by various ancient authors, as well as some miscellaneous local observations, old proverbs, etc.

Philosophical Magazine. Vol. XLV. 1898. 8vo.

The March and April parts contain a paper by Dr. C. Chree entitled: "Notes on Thermometry" (50 pp.). The points discussed are:—Natural scale of ideal thermometer; properties of real glass; fixed and movable zero scales; depression of zero; experimental relation of different scales at moderate temperatures, at temperatures over 100° C., and at low temperatures; lag; freezing and boiling points of water; calibration; external and internal pressure corrections; standard position for thermometers; emergent column; Welsh's method of graduation and its modern developments; methods of finding mean coefficient of expansion of mercury in glass; and comparison of thermometric methods.

Proceedings of the Royal Society of Edinburgh. Vol. XXI. 8vo. 1897.

Contains the following papers bearing on meteorological subjects:—Notes on clouds: by J. Aitken, F.R.S. (3 pp.).—On the seasonal death-rate from certain diseases in Edinburgh during the period 1878-94, with remarks on the relation between weather and mortality: by R. C. Mossman (11 pp. and plate).—Theoretical researches on the daily change of the temperature of the air: by Dr. J. Halm (21 pp. and plate).—The intermediate observing station on Ben Nevis: by T. S. Muir (17 pp.).

Report of the Meteorological Commission, Cape of Good Hope, for the year 1897. 105 pp. and six plates. 1898. Folio.

This report contains the results of barometrical and thermometrical observations from 46 stations, of temperature observations only from 9 stations, and of rainfall from 336 stations. Mr. A. Struben contributes some notes on Dr. Buchan's discussion of the rainfall of South Africa during the years 1885-94. Mr. Charles Stewart, who has recently been appointed Secretary of the Commission, gives a number of hints to the observers on the manipulation of the instruments and on the method of taking the observations.

Symons's Monthly Meteorological Magazine. April—September 1898. 8vo.

The principal articles are:—The climate of Paris (4 pp.).—The dry winter of 1897-98 (6 pp.).—The climate of Algeria (3 pp.).—The gloomy summers of 1860 and 1879 and the nineteen years cycle: by Rev. H. A. Boys (3 pp.).—Lightning conductors: by A. W. Preston (1 p.).—Summer rainfall: by A. B. MacDowall (2 pp.).—A long, if not unique, Well record (2 pp.). This gives a table showing the details of the level of water in a well at Chilgrove, near Chichester, for each month from 1836 to 1898.—Results of meteorological

observations at Camden Square, 1858-97 (6 pp.).—The International Aëronautical Conference at Strasburg (3 pp.).—Floods and storms in South Africa (2 pp.).—British local meteorological publications (12 pp.). In this article Mr. Symons gives a most useful catalogue of the books, pamphlets, and broadsheets referring to the weather of 1897 which have been published in the British Isles.—Evaporation and temperature (3 pp.).—Thunderstorms of July and August (3 pp.).

Weather Lore. A Collection of Proverbs, Sayings, and Rules concerning the Weather. Compiled and arranged by RICHARD INWARDS, F.R.A.S. 8vo. 1898. 233 pp.

This is the third edition of a little book which Mr. Inwards published in 1869. The present volume follows the same lines as the second edition which was issued in 1893, and contains the most extensive and complete collection of weather lore yet published. It is accompanied by a plate illustrating typical forms of clouds, together with their heights and names. The appendix contains a bibliography of weather lore.

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